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A Computational Study on Structural Behaviour of Modified Disk Brake Rotors: A Review

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Abstract:

The evolution of automotive technology has been marked by continuous advancements in safety and performance, with the disk brake system playing a pivotal role in ensuring effective vehicle deceleration. This review paper aims to provide a comprehensive overview of recent computational studies focused on the structural behaviour of modified disk brake rotors. The modification of brake rotors is an essential aspect of improving braking performance, reducing wear, and enhancing overall safety.

Keyword: Solid Modelling, Disc Brake, Ansys workbench, Thermal Analysis, Statical Analysis, Material optimization.

I. Introduction:

The disk brake system is a critical component of modern vehicles, responsible for converting kinetic energy into heat during braking. The need for improved performance, reduced weight, and enhanced durability has driven researchers to explore modifications to conventional disk brake rotors. Computational studies offer a valuable tool for understanding and predicting the structural behaviour of these modified rotors under various operating conditions.

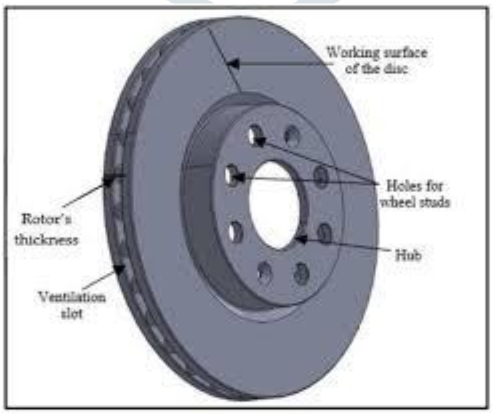

Figure 1. Disc brake

II. Material Selection and Modelling:

One key aspect of modifying disk brake rotors involves the selection of materials with improved thermal conductivity, strength, and wear resistance. Computational models play a crucial role in simulating the behaviour of these materials under the complex conditions experienced during braking. This section reviews studies that employ finite element analysis (FEA) and other numerical methods to model the mechanical properties of modified rotor materials.

a. Geometric Modifications:

Geometric modifications, such as slotting, drilling, and venting, are common strategies employed to enhance the cooling efficiency of brake rotors and reduce their weight. Computational simulations allow researchers to investigate the impact of these modifications on stress distribution, thermal performance, and overall structural integrity. This section reviews studies that focus on the geometric aspects of modified disk brake rotors.

b. Thermal Analysis:

Heat dissipation is a critical factor in the design of effective brake systems. Computational tools enable researchers to analyse the thermal behaviour of modified disk brake rotors under varying conditions. This section discusses studies that utilize thermal analysis techniques, including CFD simulations, to assess the temperature distribution and heat dissipation capabilities of modified rotor designs.

c. Wear and Friction Analysis:

Understanding the wear mechanisms and friction characteristics of modified brake rotors is essential for predicting their performance and longevity. Computational studies employing tribological models and wear simulations provide valuable insights into the wear patterns and frictional behaviour of modified rotor surfaces.

III. LITTEREATURE REVIEW:

Belhocine, Ali, et al. [1]: Ali Belhocine and colleagues used the ANSYS computer code to conduct a thorough examination into the thermal behaviour of car brake discs. Their research sought to model the disc brake's internal temperature distribution and pinpoint important variables influencing braking performance. These included the chosen material, the disc's geometric shape, and the kind of braking. The study assessed stress fields and disc deformations under pad pressure using a numerical simulation using a sequentially thermal-structural linked technique. When compared to the body of specialist literature already in existence, the outcomes of their simulation were considered satisfactory. This implies that their method of capturing the intricacies of the linked transient heat and stress fields in disc brakes is reliable.

Babukanth G. and others [2]: The thermoelastic phenomena that occurs in disk brakes was the main focus of G. Babukanth and colleagues. Using a computer model that took contact issues into account, they solved the elastic and heat conduction equations. The distribution of heat flow and temperature on friction surfaces was shown by the numerical simulations, which were run repeatedly under brake conditions. Most notably, the study examined the unstable increase of temperature and contact pressure by delving into thermoelastic instability (TIE). The study also looked at how material characteristics affect thermoelastic behaviours, with a focus on carbon-carbon composites that have good mechanical properties. This advances our knowledge of materials that can endure the harsh circumstances found in disc brakes.

Oder et al. [3]: Using the finite element approach, Oder and associates made a contribution to the subject by conducting a temperature and stress analysis of brake discs for railroad cars. Two braking scenarios were included in their analysis: stopping to a stop and stopping while moving at a steady pace on a hill. The centrifugal load, brake calliper holding force, and heat flow on the braking surfaces were important factors to take into account. This study looked at temperature and structural fields with four different materials (cast iron, cast steel, aluminium, and carbon fibre-reinforced plastic) during emergency and brief braking. The thorough method, which takes into account a number of variables that affect temperature distribution, offers insightful information for the conceptual design of disc brake systems, especially when it comes to railway applications.

M.A. Maleque et al. [4]: M.A. Maleque and team presented a technique for choosing materials for disc brake rotors, which helped. They tackled the widespread problem of cast iron's high specific gravity, which results in higher fuel consumption. The goal of the study was to provide a methodology for choosing the best material for brake disc systems, with a focus on replacing cast iron with lighter substitutes. For material selection, two new techniques were introduced: digital logic and cost per unit property. Cost was taken into account in the analysis, along with mechanical characteristics like specific gravity, wear resistance, friction coefficient, and compressive strength. The study came to the conclusion that the best material for brake disc systems was an aluminium metal matrix composite after conducting this thorough evaluation. This suggestion is consistent with the industry-wide movement toward lighter materials in order to increase efficiency.

A Daniel das et.al [5] The purpose of this work was to use four different materials to study the temperature fields and structural fields of the solid disc brake during short and emergency braking. The temperature distribution is influenced by a number of variables, including speed, surface roughness, and friction. The disc brake's temperature rises due to the interaction of contact pressure and angular velocity. The two-dimensional model's finite element simulation was chosen because of the heat flow ratio's constant circumferential distribution. With four materials—cast iron, cast steel, aluminium, and carbon fibre reinforced plastic—we will use analysis software to record the values of temperature, friction contact power, nodal displacement, and deformation for various pressure conditions. Currently, disc brakes are produced.

Table 1. Result Comparison Table.

AUTHOR NAME & YEAR	TITLE	WORK DONE	RESULT AND CONCLUSION
M.H. Pranta, M.S. Rabbi, 9 July 2021	A computational study on structural and thermal behaviour of modified disk brake rotor	Modified ventilated disk brake rotor has been developed with curved vents, holes, and slots and analyses the stress and temperature distribution. Finite element models of the rotor are shaped with SolidWorks and simulated using ANSYS. Structural and thermal characteristics are compared with a reference disk brake rotor.	Proposed rotors outperformed the conventional one in terms of stress generation, temperature distribution, and factor of safety. The result provides a physical Insight of the structural and thermal characteristics of the geometrically modified rotor that can be implemented in the automotive industry.
Mohammad Tauviqirrahman, 2023	Analysis of the effect of ventilation hole angle and material variation on thermal behaviour for car disc brakes using the finite element method.	The variation of the drill hole angles and groove hole angles is proposed as a geometry modification to encourage greater heat dissipation in disc brakes. In addition, the thermal performance of disc brakes made from various types of materials is assessed using finite element analysis.	The groove-type disc brake with a ventilation hole angle of O- angle has the lowest maximum temperature. It is revealed that the disc brake made of gray cast iron material results in the lowest peak temperature. Due to the thinning of the geometry, the addition of the ventilation hole angle contributes to the phenomena of temperature concentration in specific areas of the disc brake.
S. Mithilesh, Zubair Ahmad Tantray, 2021	Improvement in performance of vented disc brake by geometrical modification of rotor	Two stage modification is carried out on the existing braking of vented disk brakes and analysis is carried out using simulation- based software Ansys to improve the life span and stress characteristics. In the modification mainly hole diameter of the disc and contact area between brake pad and disc are varied by keeping in view the total weight of the braking system.	It is found to be better in stress characteristics as the maximum stress reduced 18.9% and has also shown significant improvement in minimum life span of the braking system. With increase in hole diameter the heat dissipation will be better as more heat can flow easily through the larger holes.

Ali Belhocine, Mostefa Bouchetara, 17 August 2012	Investigation of temperature and thermal stress in ventilated disc brake based on 3D thermomechanical coupling model.	The numerical simulation for the coupled transient thermal field and stress field is carried out by sequentially thermal-structural coupled method based on ANSYS to evaluate the stress fields and of deformations which are established in the disc and the contact pressure on the pads.	The highest temperatures are reached at the contact surface disc-pads. The strong rise in temperature is due to the short duration of the braking phase and to the speed of the physical phenomenon.

IV. Overall Review:

The collection of studies provides a comprehensive exploration of the thermal and structural aspects of disc brakes in vehicles, covering various factors such as braking conditions, material properties, and geometric design. The use of advanced numerical simulations and finite element methods enhances the understanding of complex phenomena, offering insights that can contribute to the optimization of disc brake systems. The studies collectively underscore the importance of considering multiple factors in designing efficient and reliable braking systems for different applications. The emphasis on material selection and the shift towards lightweight alternatives aligns with the broader automotive industry's pursuit of improved performance and fuel efficiency. These studies collectively contribute to the evolving knowledge base in the field of brake system engineering.

V. Performance Evaluation:

The ultimate goal of modifying disk brake rotors is to enhance overall braking performance. This section reviews computational studies that evaluate the performance of modified rotors through simulations of braking events, considering factors such as stopping distance, fade resistance, and stability under different operating conditions.

VI. Challenges and Future Directions:

Despite the progress made in understanding the structural behaviour of modified disk brake rotors through computational studies, several challenges remain. This section discusses current limitations, such as the need for more accurate material models and the integration of Ansys simulations. Additionally, potential avenues for future research, including the exploration of advanced materials and innovative design concepts, are highlighted.

VII. Conclusion:

In conclusion, this review provides a comprehensive overview of recent computational studies on the structural behaviour of modified disk brake rotors. The integration of advanced numerical techniques has significantly contributed to our understanding of the complex interactions involved in brake system dynamics. As automotive technology continues to evolve, further research in this field will play a crucial role in enhancing the safety and performance of disk brake systems.

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