IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

Enhancing Ventilated Disc Brake Rotors: A Thorough Computational Analysis Utilizing Ansys

Rakesh kushwaha[1st] S.S. Chauhan [2nd] Prakash Pandey [3rd]
[1]Department of Machine Design, Vaishnavi Group of Institutions, Bhopal
[2]Department of Machine Design, Vaishnavi Group of Institutions, Bhopal
[3]Department of Machine Design, Vaishnavi Group of Institutions, Bhopal

Abstract: The research explores the advancement in automotive braking systems, particularly focusing on the disk brake rotor's design and performance. Newton's 1st law of motion serves as a fundamental principle, emphasizing the need for an efficient braking system in vehicles. The study delves into the transformation of kinetic energy into thermal energy in brakes and the implications of heat management on braking efficiency. It categorizes brakes, discusses various types (mechanical, hydraulic, pneumatic, vacuum), and introduces disk brake systems. The research employs ANSYS for computational analysis, aiming to optimize the structural and thermal characteristics of disk brake rotors. The study's novelty lies in its approach to modifying rotor designs for enhanced performance, investigating variables like temperature, heat flux, stress, deformation, and safety.

Index Terms **- Automotive Braking Systems, Disk Brake Rotor, Kinetic Energy, Thermal Energy, ANSYS, Computational Analysis, Heat Management, Brake Efficienc.**

I. INTRODUCTION

“Newton 's 1st law of movement states that "An item remains in its position of rest or in movement until and unless did act upon by an external power." This law besides Sir Isaac Newton led to the improvement of the brake in an automobile, as improving an automobile vehicle needs both an efficient braking system and a power source with sufficient horsepower [1]. This idea sparked a great deal of brake research, which led to the field's progress and provided us the freedom to select the best braking system for our needs today.

A braking device in a motor car is a configuration of different linkages and parts (brake lines or robotic links, brake drum or brake disc, master cylinder or fulcrums, etc.) arranged in such a way that it transforms the kinetic energy of the vehicle into heat vitality, which then stops or decelerates the vehicle [2].

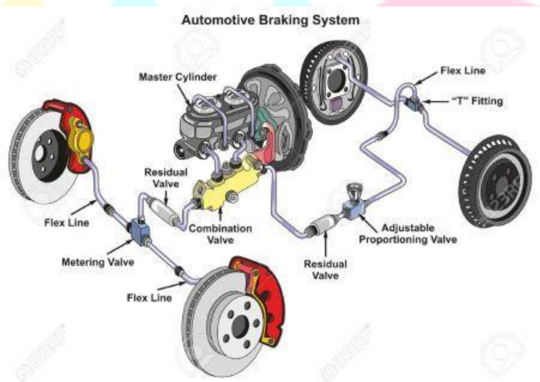


Figure 1 Automotive Braking System

[Source- https://studentlesson.com/automotive-braking-system-definition-functions-working/]

The braking mechanism of a device, be it in vehicles, machinery, or other equipment, relies heavily on the transformation of kinetic energy into thermal energy through the frictional interaction between brake pads (or shoes) and a rotating drum or disc. This frictional power, generated by the contact of these components, acts as the primary force that decelerates and halts the movement. Essentially, the effectiveness of a brake system is intrinsically linked to how efficiently it can produce and dissipate this heat. If not managed properly, excessive heat can lead to brake fade, reduced performance, and even potential failure of the braking system. Hence, understanding and optimizing the heat conversion and dissipation process is paramount for ensuring the safety and efficiency of any braking system. The reference [3] might delve deeper into these concepts, emphasizing the criticality of proper brake design and maintenance in ensuring safe and optimal operations.

- To stop the moving vehicle.
- To de accelerate the moving vehicle.
- For stable parking of a vehicle either on a flat surface or on a slope.
- As a precaution for accidents.
- To prevent the vehicle from any damage due to road conditions.

1.1 Classification of Brakes

The journey from vintage carts to state-of-the-art cars and from age-old carriages to contemporary trucks has been a testament to the incredible advancements in braking technology. As vehicles evolved, so did their braking systems, tailored to cater to the unique needs and functionalities of each era and type of vehicle. These braking systems have been meticulously designed considering the varied purposes and requirements of different automobiles. The classification of brakes, especially when categorized by power source, further underscores the diversity and specialization in their design. As illustrated in figure 2, there are six distinct categories into which these brakes fall. This categorization not only highlights the breadth of technology employed in modern braking systems but also emphasizes how each type is optimized for its intended function, ensuring both safety and efficiency in various vehicular contexts referenced in [4]. The nuances and complications of each category potentially offer a deep dive into the fascinating world of brake engineering and its continual evolution.

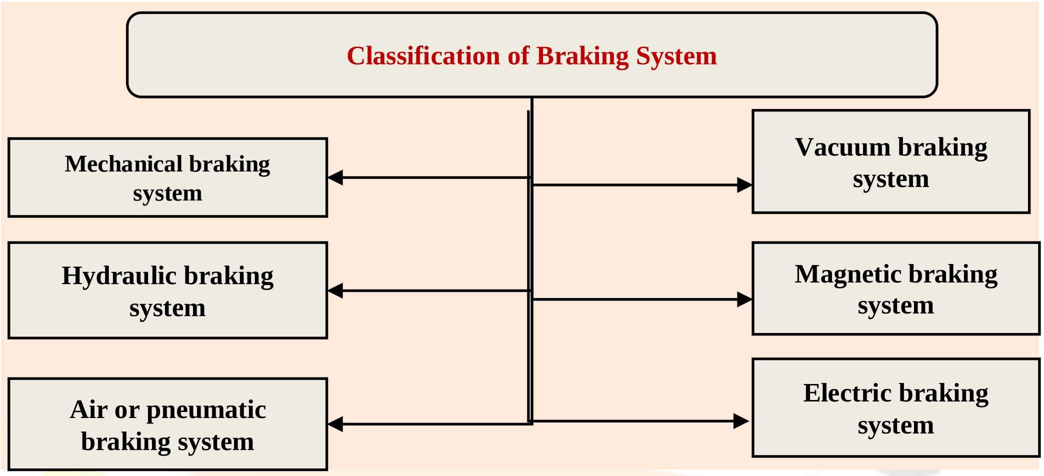


Figure 2 Classification of Braking System

1.2 Mechanical system

Mechanical brakes operate fundamentally on the principle of generating frictional forces when two interacting surfaces come into contact. Their efficacy in halting a moving object, whether it's a bicycle or a large vehicle, is chiefly dictated by two main factors: the surface area of the frictional interfaces and the force exerted during actuation, as highlighted in [5]. Larger surface areas and greater actuation forces typically equate to more stopping power. However, this frictional interaction isn't without its consequences.

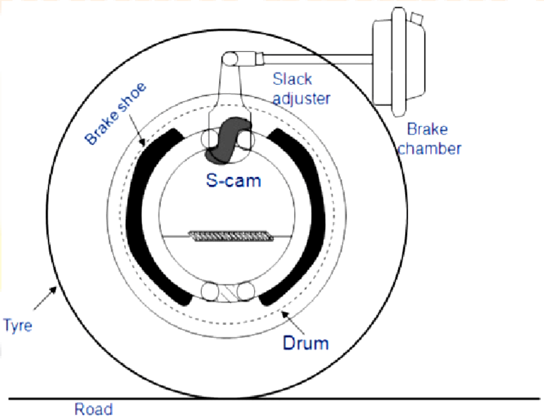


Figure 3 Mechanical Brake System [6]

1.3 Hydraulic Brakes

Rooted in Pascal's law, these brakes operate on the premise that any applied pressure on a fluid within an enclosed system disperses uniformly in all directions. This ensures a balanced and even braking force on all wheels, making for safer and more consistent stopping power. When a driver presses the brake pedal, this force doesn't act directly on the brakes. Instead, it is transmitted through a specialized brake fluid, acting as a link, which then transfers this force to the brake shoes.

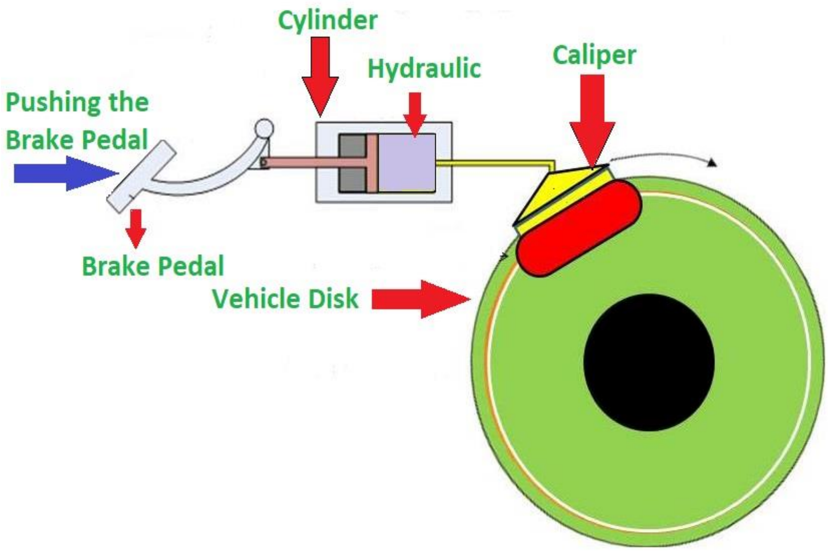


Figure 4 Hydraulic Brakes System

1.4 Pneumatic Braking System

The pneumatic braking system is one of the types of Automobile Braking System. It is also known as the Air braking system. The Brake force produce by the Hydraulic Brake is not sufficient to stop the heavy vehicles. Therefore Pneumatic Brake is used in heavy vehicles. The five Basic components of a Pneumatic or Air brake system are Air Compressor, Storage Tank/Air Reservoir, Brake Valve, Brake Chamber, Brake Drum.

Air brakes are mainly used in heavy vehicles like busses and trucks because hydraulic brakes fails to transmit high brake force through greater distance and also pneumatic brakes generates higher brake force than hydraulic brake which is the need of the heavy vehicle.

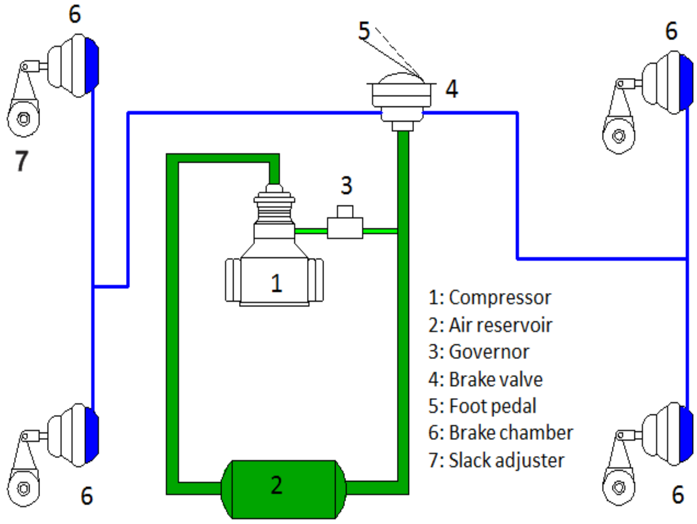


Figure 5 Air Braking System

[Source - https://www.mechanicalbooster.com/2017/12/air-brake-system.html]

1.5 Vacuum Brakes

Vacuum Braking System is one of the types of braking system, were mostly used in railway locomotives in the mid 1860's before the invention of Air Brakes. Railway locomotives were used Vacuum brakes instead of air brakes. Vacuum Brakes mainly consists Brake pipes, Brake Cylinder, and Vacuum Reservoir. The Vacuum pump in Vacuum Brake System creates vacuum in the brake pipe; and the brake cylinder uses the vacuum reservoir for applying the brakes.

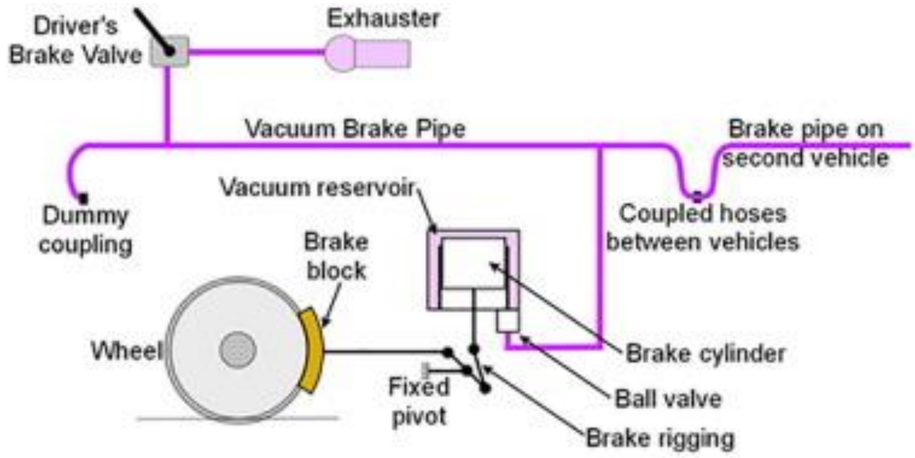


Figure 6 Vacuum Braking System [4]

1.6 Working Procedure of Disk Brake System

Disc brakes have long been a preferred choice for passenger vehicles due to their superior performance, especially at elevated speeds. Their inherent design promotes efficient heat dissipation, which offers notable resistance to brake fade—a phenomenon where braking efficiency decreases with excessive heat. This fade resistance ensures consistent stopping power even under strenuous driving conditions. While drum brakes have historically dominated the commercial vehicle segment, primarily because of their longevity and cost-effectiveness, the landscape is shifting.

1.7 Construction

The braking process is an intricate interplay of various components, all designed to ensure the safe deceleration of the vehicle. As a vehicle moves, the brake rotor, or disc, rotates in tandem with the wheel. When the driver applies pressure to the brake pedal, this action activates the brake booster—a servo system that magnifies the applied force. This augmented force is then transformed into hydraulic pressure by the master cylinder. This hydraulic pressure, carried by brake oil or fluid through a network of tubing, is transmitted to the brakes at each wheel. At the wheel's end, this pressure prompts the pistons inside the brake calipers to move.

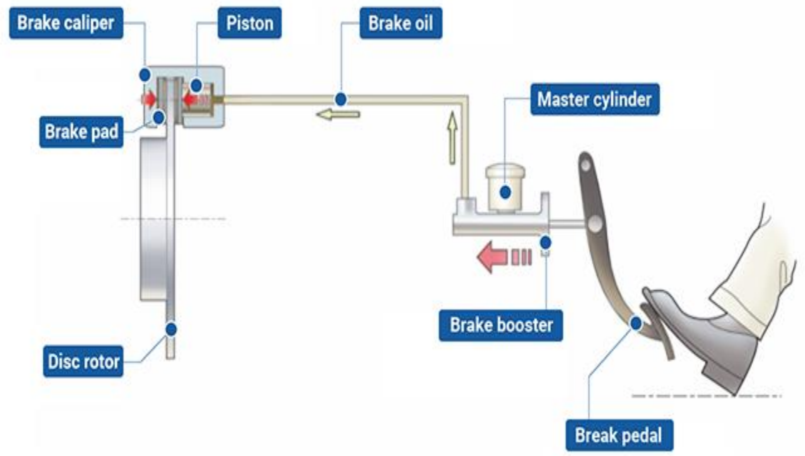


Figure 7 Working of Disk Brake

Disc brakes, a crucial component in modern vehicles, mainly come in two varieties. The first, the "opposed piston type disc brake," incorporates pistons on both flanks of the disc rotor, ensuring symmetrical pressure application. Contrarily, the "floating type disc brake" employs a single piston on one side. Due to its design and mechanism, the latter is often referred to as the "sliding pin type disc brake." This research is laser-focused on the intricate design intricacies of disk brake rotors.

II LITERATURE REVIEW

Asif Afzal [7] The disc brake system, a pivotal automotive component, operates within complex and dynamic nonlinear transient heat and mass transfer conditions. Achieving the optimal design for a braking system that meets criteria encompassing heat dissipation, weight, and space efficiency remains a persistent challenge. To address the multifaceted challenges pertaining to the thermal, mechanical, and structural performance of vehicle disc brakes, extensive research efforts have been undertaken and continue to evolve. This evolution has been significantly facilitated by the widespread adoption of numerical tools and methodologies. This comprehensive analysis delves into both computational and experimental investigations surrounding the design of solid and perforated disc brakes, which have been previously documented. Furthermore, it highlights potential directions for future research endeavors, underscoring the ample opportunities for further exploration to realize the ultimate design of a disc brake system through precise simulation of all pertinent real-world conditions.

P Shiva Shanker [8] The most crucial component of an automobile that maintains comfort and safety is the brake. In order to investigate vehicle braking systems, several braking techniques and processes are reviewed in this research. It discusses various braking system types, material characteristics, and various materials used in the production of brakes, particularly disc brakes. From the earlier study publications, the benefits and drawbacks of each sort of braking strategy were analyzed. This study will be useful for figuring out how to enhance the braking system's functionality and performance, boost fuel efficiency, and lighten the weight of cars. Additionally, it addresses the materials employed in earlier investigations as well as the utilization of various traditional materials, such as cast iron and Metal Matrix Composites (MMCs) materials. MMCs have significantly improved over the past two decades, largely because to their superior physical, mechanical, and tribological qualities when compared to monolithic materials. The increased strength, hardness, and weight reduction of MMCs over other materials are its main advantages. It is discovered that the analysis continues to follow the methodology recommended by the automotive industry.

Michael D. Atkins [9] The thermal performance of a brake disc, or its resistance to brake fade, brake wear, thermal distortion, and thermal cracking, is determined by the flow pattern through the vented channel of the brake disc. The flow parameters inside the vented channel of a radial vane braking rotor with a chosen number of vanes—18, 36, or 72—but constant porosity (0.8) at low rotational speeds—25 rpm N 400 rpm—are the subject of the experiments presented here. We found that increasing the number of vanes for a given rotational speed causes an increase in the mass flow rate of the air pumped by the rotor, a decrease in the inflow angle (), more equally balanced passage velocity profiles, and an increase in Rossby number. These findings were made using bulk flow and tangential velocity mapping measurement techniques. Additionally, we discovered biased formation of stream-wise secondary flow structures in the vented passageways that only occur on the inboard side of the rotor during a specific range of rotational speeds (i.e., 100 rpm N 400 rpm). This is because, as air is sucked into the spinning tube, the incoming flow must abruptly change from an axial to a radial direction. The biased secondary flow could result in thermal distortion by cooling the brake rotor unevenly. The biased secondary flows change into a symmetric structure at slower rotational speeds (i.e., N 100 rpm).

Wanyang Li [10] This article mostly examines the state of ceramics research and market trends for automotive disc brakes. Numerous qualities and traits, such as fracture toughness, strength, compactness, corrosion resistance, wear resistance, micro-morphology, and thermal stabilities are examined in relation to ceramic disc brakes. The research directions for ceramics in the area of disc brakes are examined. These directions include high-temperature performance, bionic structures, layered structure, porous structure, eutectic acting skills, superhard structure, and machinability. It is anticipated that disc-brake materials will be discovered through ceramics investigation to be in accordance with future development trends.

Mr. Sumeet Satope [11] The brake system and every other component of an automobile have advanced significantly in recent years. In two-wheeler brake systems, alloy martensitic stainless steel and, sporadically, carbon-carbon composite and grey cast iron are utilized for the disc brakes. However, when brakes are faced with structural and wear concerns, it is crucial to conduct analytical calculations in order to acquire temperature, heat flow, heat generated, etc. with the help of which the best material is chosen in accordance with the needs of the vehicle system. The goal of the two-wheeler disc brake's steady state thermal analysis of the rotor was to assess how well it braked under braking conditions. This work uses mathematics inputs and brake rotor thermal loads to calculate the various parameters needed for thermal analysis under predictions based. Solid Works 15 is used for the design of the brake rotor, and Ansys 14.5 is used for the analysis.

Daanvir Karan Dhir [12] While braking, the vehicle's kinetic energy is transformed into mechanical energy, which causes the disc and the disc-pads to heat up and lose heat. The objective of this work was to use the finite element method to examine the temperature that rises of an automotive disc brake during braking and its impact on disc durability. Heat flux was produced when a specific braking torque was applied to the rotor. Numerical analysis of the heat flux produced and the thermal conductivity taken into account was used to determine the stiffness of the rotor and the maximum thermal expansion on the disc rotor. The durability and fatigue factor of the disc's safety were examined using thermo-mechanical cyclic forces that were applied to the rotor further. By modeling and using FEM techniques in Solid Works and ANSYS, respectively, the effect of modifications in disc rotor configuration, such as holes and airfoil vents, in comparison to a simple flange type disc, were analyzed, and their effect on maximum temperature rise and disc durability were researched.

Shah E Alam [13] The authors of this work provide the findings of a thermal examination of an Indian two-disc wheeler's brake rotor. Understanding the function of the holes in the disk brake is the goal of this essay. Two alternative rotor types are subjected to thermal study. One has a straightforward rotor with no vents or holes, while the other is perforated (consists of holes). The heat loss from a rotor, which is thought to be overheated by disc brake friction when in use, has been studied by researchers. Researchers include radiation and convection while analyzing heat loss. The outcomes for both discs are compared. Here, it is first presumed that the car has totally stopped due to the application of brakes. The dimensions of both rotors are the same. Solid-Works is used to create the geometry of the braking system. Utilizing ANSYS software, the heat transport study is carried out. The research enables us to comprehend which of the two models performs better, loses less heat, and has a lower production cost, making it more widely utilized in motorcycles in the actual world.

C. Baron Saiz [14] The heat generated by the contact between the brake pads and the disc cannot completely disperse during the braking phase. As a result, the brake disc, particularly when really heavy braking occurs, can quickly build up a lot of heat, leading to high temperature gradients on it. The brake system's functionality and safety may be jeopardized in these circumstances. The goal of this study is to examine the thermomechanical behavior of several brake rotors under challenging operating conditions, assess their effectiveness and stability, and locate any potentially dangerous flaws. In particular, one whole disc and three ventilated rotors with various shapes have been examined using FEM thermo-mechanical coupled analyses. The achievements of the discs in terms of temperature distribution, stresses, and strains have been assessed using a very demanding (fading) test. The obtained results show that, in contrast to a complete rotor, the investigated ventilated discs can be employed efficiently under very demanding working situations while consistently ensuring high safety levels. The disc with curved vanes was judged to be the best option among the rotors that were investigated.

III. OBJECTIVE

The goal of the project is to investigate computational analysis using ANSYS to ascertain the structural and thermal characteristics of changed disk brake rotors.

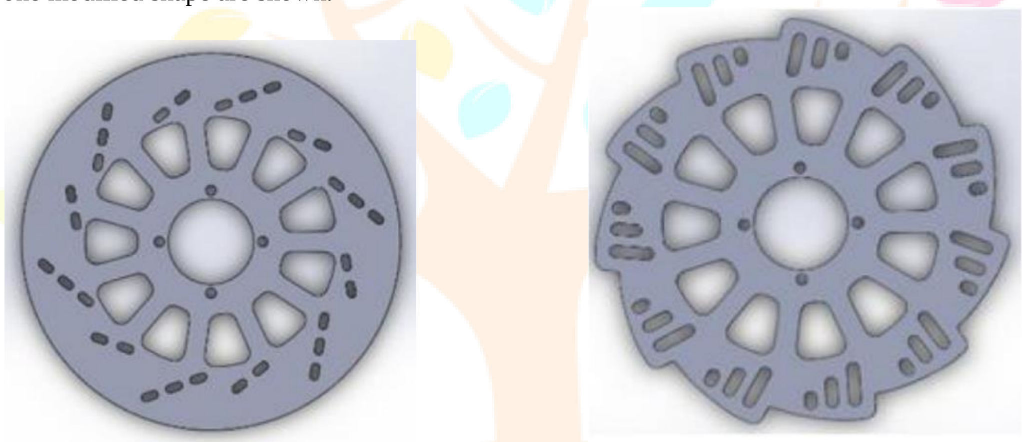
- Steady-state thermal analysis for suggested disk braking rotors will be studied.
- To examine, static structure analysis for suggested disk brake rotors.
- To contrast the features of the suggested model, the modified model, and the base model.
- To calculate the values of the following five criteria: temperature, heat flux, equivalent stress, deformation, and safety factor.
- To discover novel results from the suggested model.

IV. METHODOLOGY

More information on the research philosophy is provided below. The research is highlighted in this section, with the first step being the creation of a disc brake prototype using ANSYS with some design modifications, followed by the selection of the rotor material based on its properties and use as a disc, the execution of theoretical calculations based on the properties of the front disc brake using the energy-saving methodology, and the comparison of the results with quantitative ones.

4.1 Proposed Methodology

One of the essential and safety-critical parts of a car is the brake mechanism. Significant improvement during the braking mechanism is provided by a correct rotor design and superior heat dissipation material. This study examines the stress and temperature distribution in a modified ventilated disk brake rotor that has been developed with curved vents, holes, and slots. It is expected that it is stress-free prior to using the brake. The effects of inertia and body force were deemed to be insignificant. In Fig. 4.1, a real-world model and one modified shape are shown.



(A) (B)

Figure 8 Base Model and Modified Model

It should be noticed that Fig. 4.1 displays the face image design and features of the disk brake versions. All of the models that were created and examined for this study are ventilated models. Table 1 lists the characteristics that all models share in common.

Table 4.1 General features used to generate the model

Feature	Details
Outer diameter	200 mm
Inner diameter	150 mm
Thick ness	3.5 mm
Brake pad surface (area)	35mm (3848.45 mm^2)
Wheel hub support	4
Material (yield strength)	Stainless steel (207MPa)
Co-efficient of friction	0.5
Maximum pressure applied	1MPa

4.2 Finite Element Analysis (FEA)

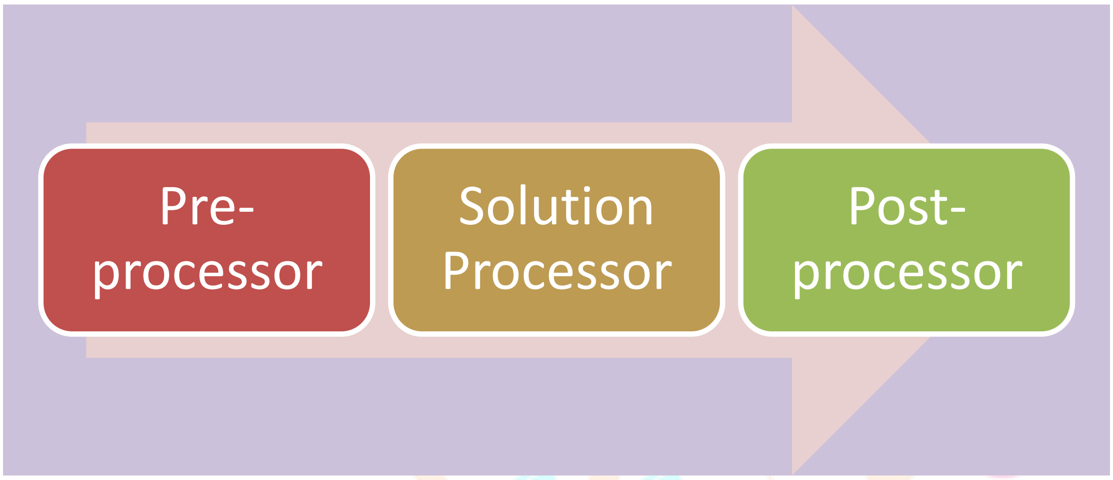
To tackle complicated engineering issues, there are three general approaches: analytical methods, experimental methods, and numerical methods. Although analytical approaches offer precise answers, they can only handle simple geometries. Experimental techniques can produce precise results, but they are expensive and frequently not financially viable. Engineering issues can be solved numerically using the finite element analysis (FEA) approach, which is a very flexible and thorough numerical tool. The discretization of a given domain into a collection of straightforward subdomains known as finite elements is the key component of FEA. The modeling and subsequent analysis are more accurate the more of these finite elements there are. The finite element method is a numerical technique focused on efficiently resolving differential equations.

Any equation with derivatives, whether ordinary or partial, is referred to as a differential equation. They could be linear, partial, or regular. Differential equations are significant from an environmental standpoint because they serve as a representation of the language used to convey physical laws. It is the goal of FEA to convert a system's differential equations into a collection of linear equations so that they may be solved by computer software.

Ansys Software

Treatment of nonlinear equations essentially consists of three steps: model creation, problem solving, and outcome analysis. The three primary components of Ansys, like many other FEA systems, are the processors, also known as pre-processor, solution processor, and post-processor.

Users can create topology, define materials, and create element mesh using the Ansys pre-processor. Users of the Ansys processor can apply loads on problems to find solutions. The Ansys post-processor enables tabular results listing and visualization, as well as hardcopy of the data.



A design process can access almost any area of engineering simulation thanks to Ansys' extensive software suite, which covers the whole spectrum of physics. Companies all across the world rely on Ansys to provide the highest return possible on their investment in engineering simulation software.

The difficulty of integrating different components into a system to ensure they function as intended increases as products get more complex. Use cases for Ansys include computer modeling, industrial applications, tooling, and automotive and aerospace design. Ansys is utilized everywhere FEA is employed. It is a really potent tool with a ton of capability because it is one that focuses on FEA applications and has done so for many years.

4.3 Topology Optimization

The research undertaken in this study is dedicated to the enhancement of ventilated disk brake rotors, which have been customized with curved vents and slots. The primary focus is on assessing the distribution of stress and temperature within these modified brake rotors. To achieve this, Finite Element Models of the rotor were meticulously crafted using SolidWorks, a powerful 3D design software, and subsequently, advanced simulations were performed using ANSYS, a sophisticated engineering simulation tool. To optimize the structure and its parameters we have to use topology optimization toolbox given in the software. For optimization just left click on it drag and put it on solution when as we put it on solution the result will be shared. To link topology optimization with static structure, just open the setup tool and results will be shared. These are the result which we calculated previously and now the topology optimisation is link to statics stucture just right click on solution then click on solve.

Static structural result which we have calculate previously and now the topology optimization is linked to static structural just right click on solution then click on solve again visit on the option of response constraint where we can retain the mass and percentage to retain please it. In this work we have seen that 50% is needed to retain the mass click on solution and it is done topology density can be seen as the figure given below.

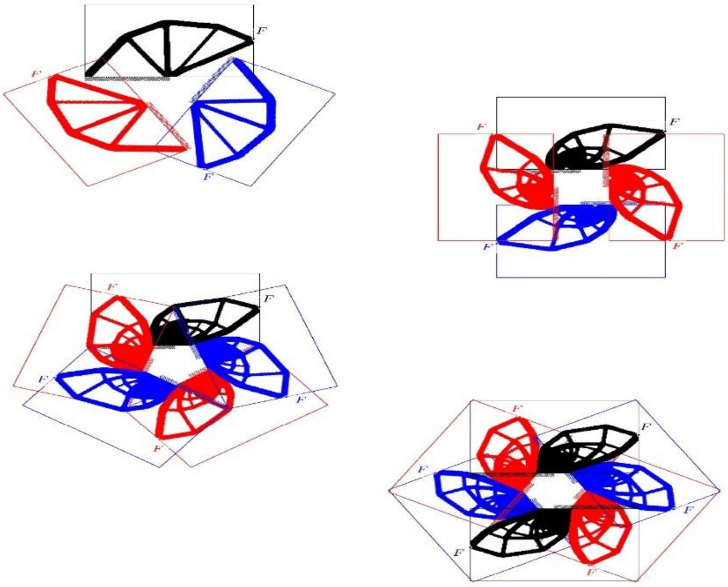


Figure 9 Topology optimization having 50% of mass reduction

The percentage of mass reduction can be varied by using this toolbox. We can also optimize the topology density. Topology density when we click on this option we can see the this optimization whatever the material is not taking part in the analysis is removed using this analysis you can optimise or reduce or reduce the mass of the design unwanted mass is eliminated from the design we can see here the designed is like this but when we go for the design optimisation with the help of topology optimisation tool our design is optimise to this level means this is the unwanted material which is removed from this geometry.

4.4 Material Property of steel

Table 4.6 Material Property of steel

Properties	**Steel**
Tensile Strength	400 (MPa)
Poisson's Ratio	0.3
Mass Density	7850 Kg/m^3

4.5 Grid independent test

Grid independent is associated with the accuracy of numerical results, the grid is independent directly influences the truncation error or even the rationality of numerical results. When considering grid-independent test, a very dense grid can avoid this problem but the calculation resource may be wasted unnecessarily. In practice, we usually increase the grid resolution according to a certain ratio and then compare the results of two neighborhood results. If the results tend towards identical the grid can be considered as grid-independent. Such strategy can utilize computational resource most efficiently as well as obtain reasonable results.

Table 4.7 Thermal and Static structural values of mesh independent test

Thermal and Static structural values of mesh independent test				
NO. OF ELEMENTS	TEMPERATURE °C	HEAT FLUX W/mm^2	EQUIVALENT STRESS Mpa	TOTAL DEFORMATION mm
6478	151.563	102873	79.602	0.035586
11202	151.568	99270	83.637	0.035623
254893	151.569	99021	81.612	0.035621
464639	151.569	99021	81.612	0.0356213
489612	151.569	99021	81.612	0.035621

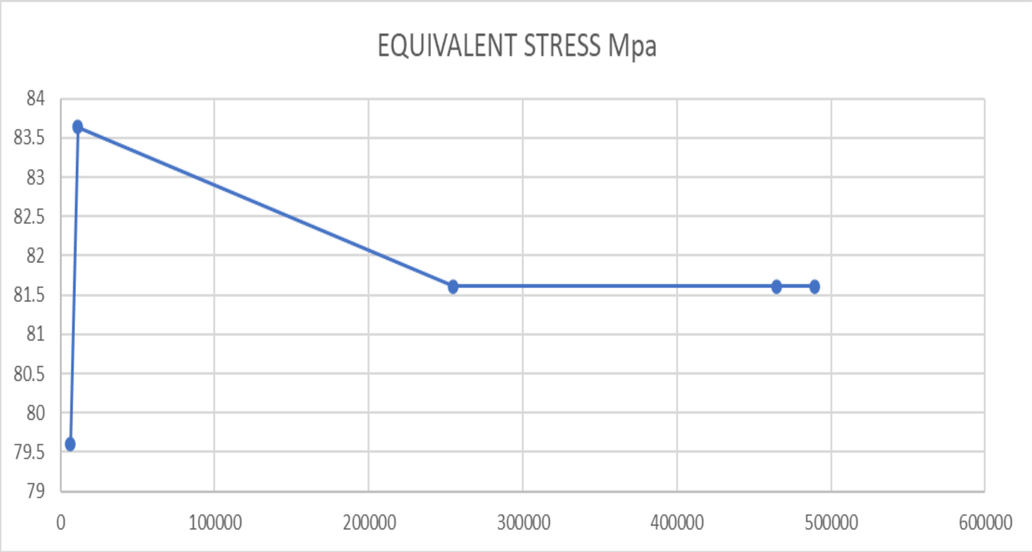


Figure 10 Grid independent test for Equivalent Stress

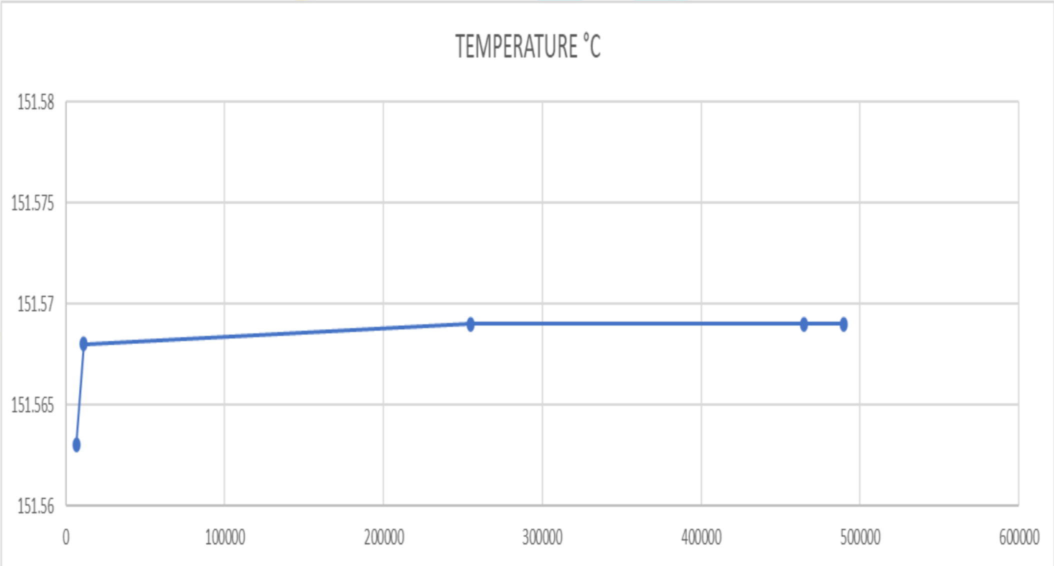


Figure 11 Grid independent test for temperature

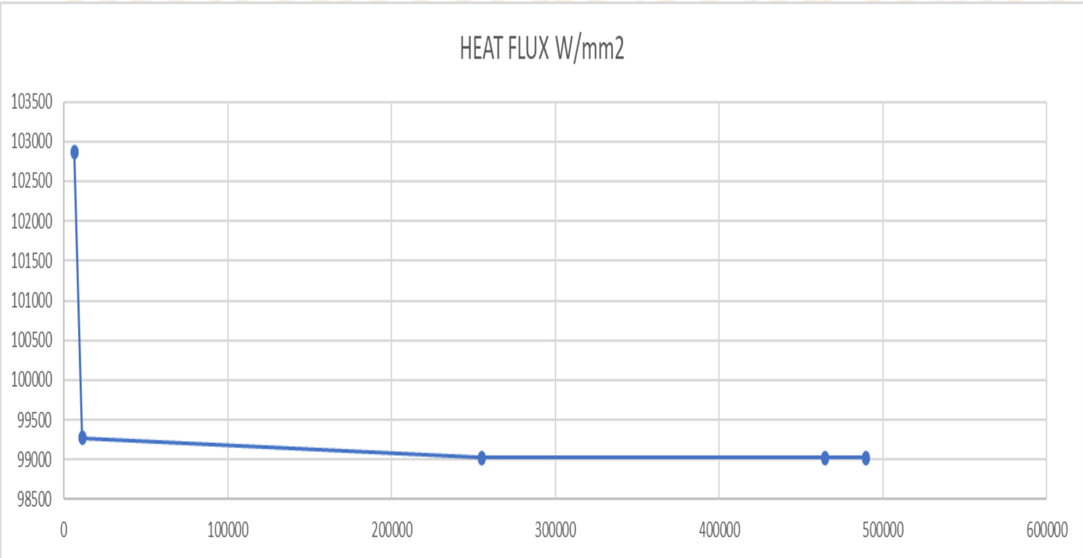


Figure 12 Grid independent test for heat flux

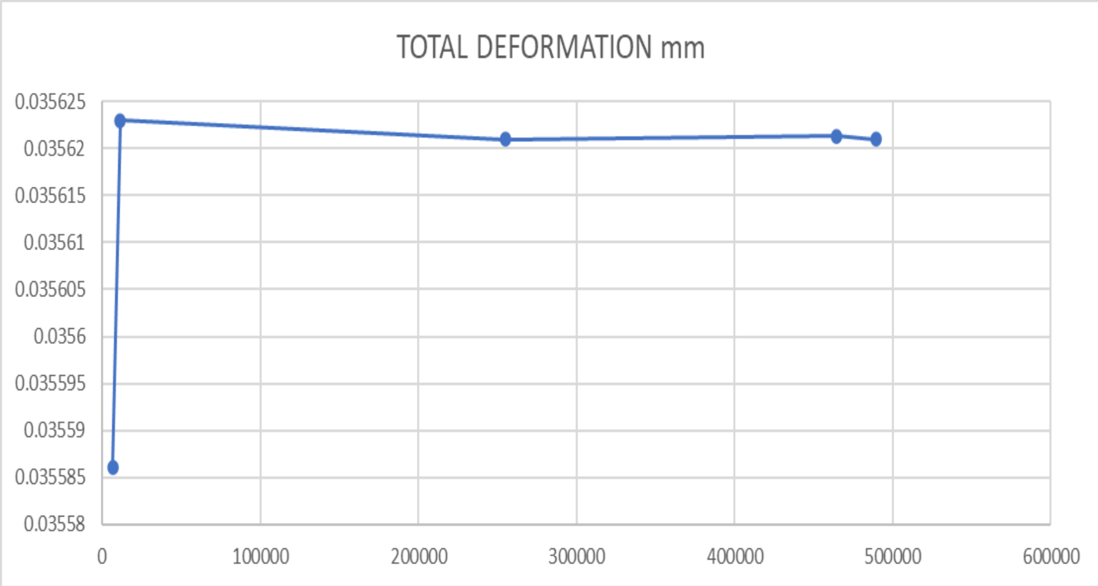


Figure 13 Grid independent test for total deformation

V. RESEARCH METHODOLOGY

5.1 Comparative Analysis

This section shows the comparative analysis of total deformation, total heat flux, equivalent stress and temperature in base model, modified model, proposed model (case 1 and case 2) which we have created in this research work.

5.1.1 Comparative analysis of Total Deformation in all the models

Table 5.1 Total Deformation in all the models

Models	Total Deformation (mm)
Base Model	0.035621
Modified Model	0.031674
Proposed Model (Case 1)	0.031615
Proposed Model (Case 2)	0.026386

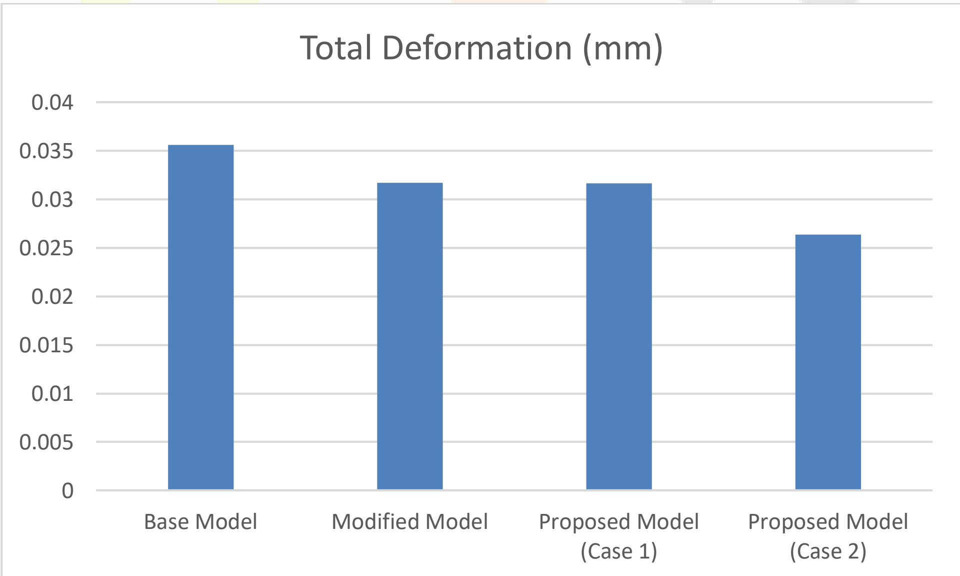


Figure 14 Graphical representation of total deformation in all the models

The above graph shown in figure 14 depicts that the maximum value of total deformation obtained in base model i.e; 0.035621 mm. Whereas, proposed model (case 2) shows the minimum value of total deformation i.e; 0.026386 mm.

5.1.2 Comparative analysis of Total Heat Flux in all the models

Table 5.2 Total Heat Flux in all the models

Models	Total Heat Flux(W/mm^2)
Base Model	0.099025
Modified Model	0.072034
Proposed Model (Case 1)	0.15142
Proposed Model (Case 2)	0.16509

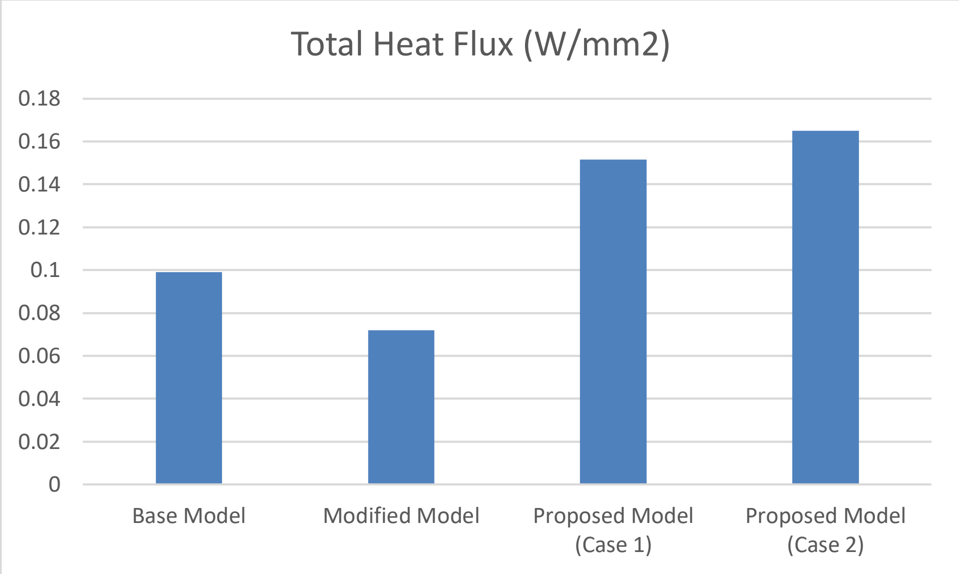


Figure 15 Graphical representation of total heat flux in all the models

The above graph shown in figure 15 depicts that the minimum value of total heat flux obtained in modified model i.e; 0.072034 (W/mm^2). Whereas, proposed model (case 2) shows the maximum value of total heat flux i.e; 0.16509 (W/mm^2).

5.1.3 Comparative analysis of Temperature in all the models

Table 5.3 Temperature in all the models

Models	Temperature (ºC)
Base Model	151.57
Modified Model	146.06
Proposed Model (Case 1)	139.12
Proposed Model (Case 2)	130.84

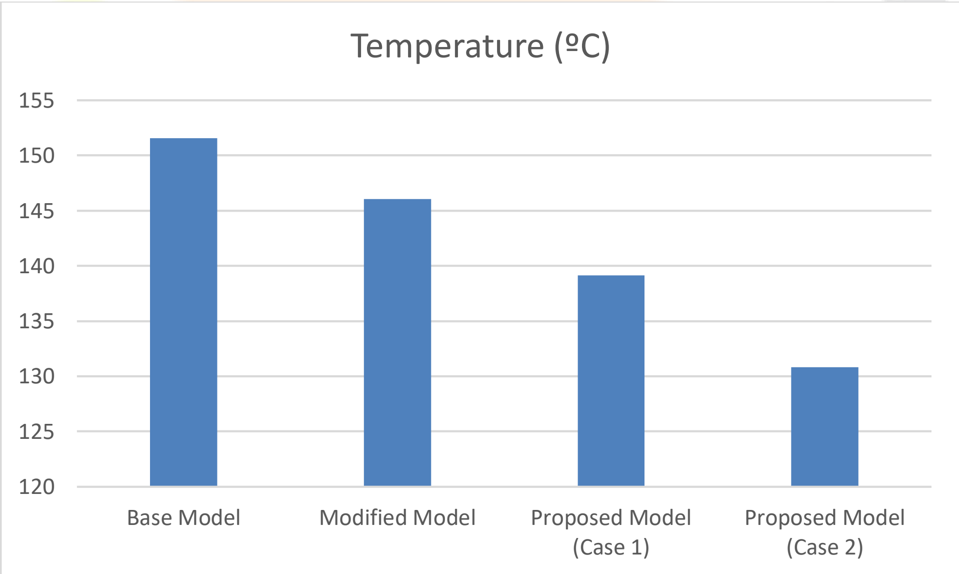


Figure 16 Graphical representation of temperature distribution in all the models

The above graph shown in figure 16 depicts that the maximum value of temperature distribution obtained in base model i.e; 151.57ºC. Whereas, proposed model (case 2) shows the minimum value of temperature distribution i.e; 130.84ºC.

5.1.4 Comparative analysis of Equivalent Stress in all the models

Table 5.4 Equivalent Stress in all the models

Models	Equivalent Stress (MPa)
Base Model	88.612
Modified Model	71.424
Proposed Model (Case 1)	76.890
Proposed Model (Case 2)	70.497

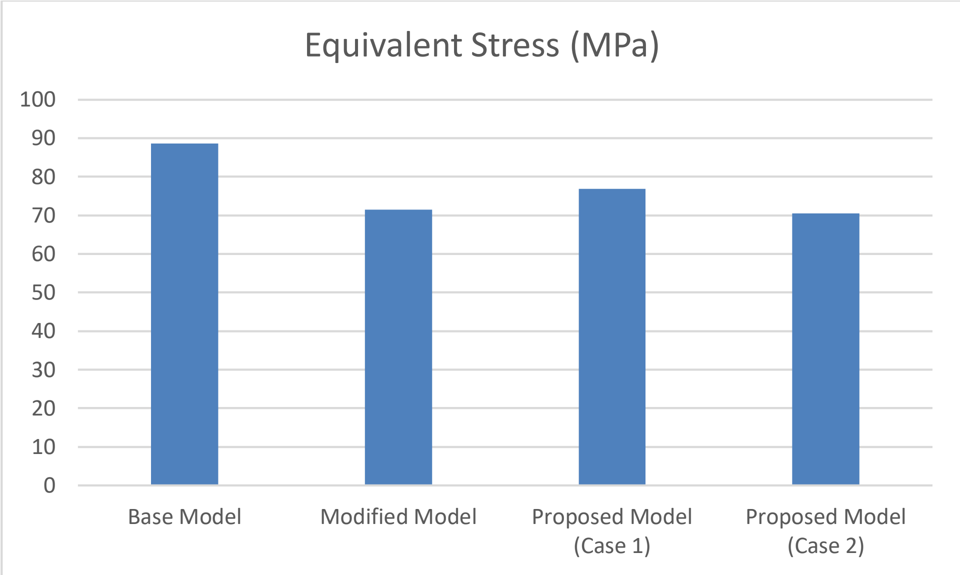


Figure 17 Graphical representation of equivalent stress in all the models

The above graph shown in figure 17 depicts that the maximum value of equivalent stress is obtained in base model i.e; 88.612 MPa. Whereas, proposed model (case 2) shows the minimum value of equivalent stress i.e; 70.497 MPa.

5.2 Comparative analysis of the three models in Stress and Deformation

Comparison of stress and deformation was shown in figure and also we can observe the improvement in stress and deformation.

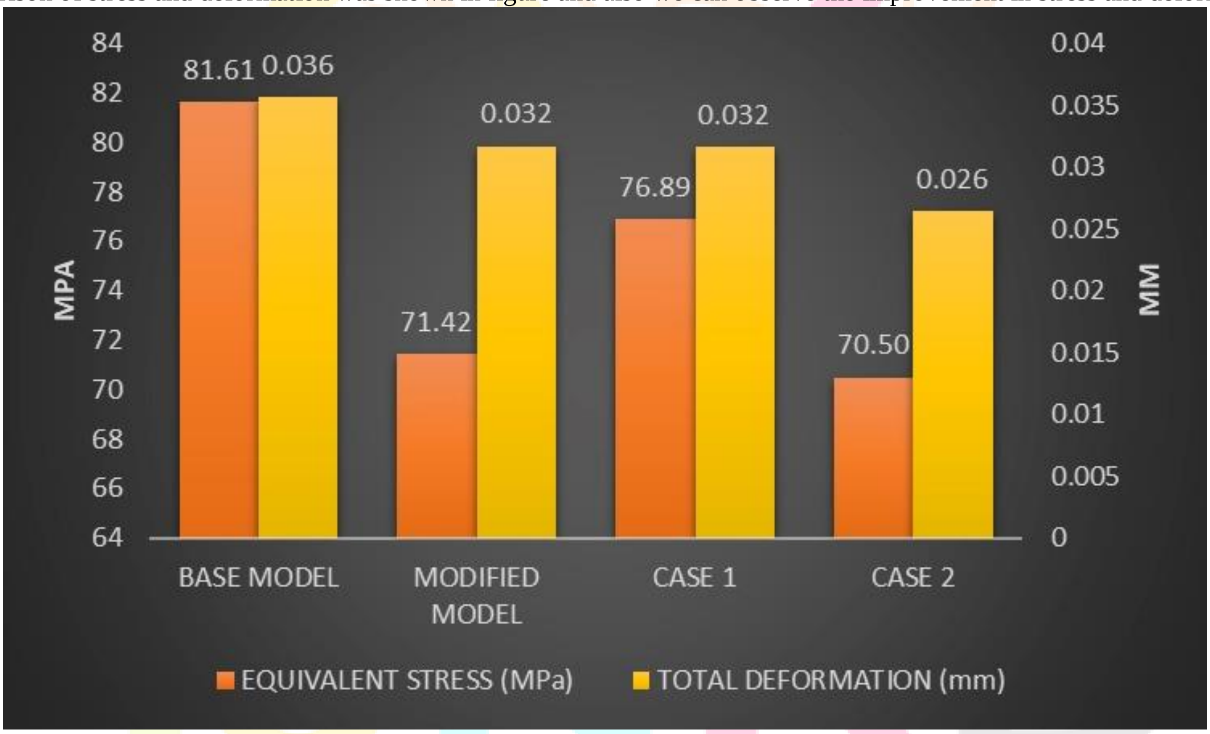


Figure 18 Graphical Comparison of the three models on basis of Stress and Deformation

While comparing the equivalent stress of all the models we can see from the graph above that, the maximum value of stress is found in base model i.e; 81.61 MPa which is reduced in our proposed model and the value obtained is 70.50 MPa. Similarly, on comparing total deformation of all the models, the above graph shows that base model has maximum value of deformation i.e; 0.036 mm whereas our proposed model reduces this value to 0.026 mm.

5.2.1 Comparative analysis of the three models in temperature and Total heat flux

Comparison of temperature and Total heat flux was shown in figure, and also we can observe the improvement in temperature and Total heat flux.

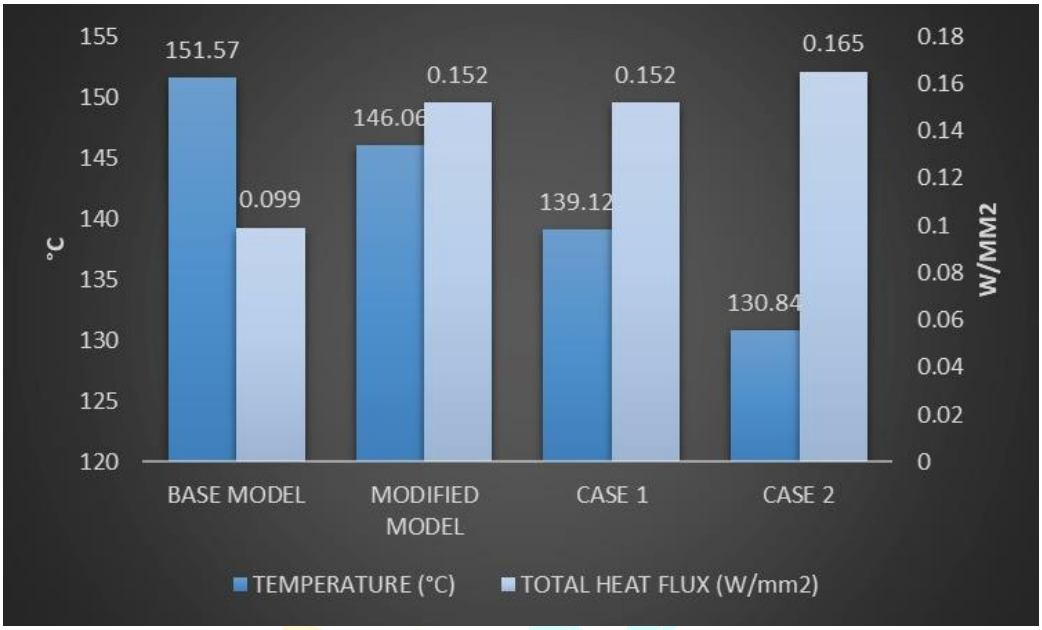


Figure 19 Graphical Comparison of the three models on basis of temperature and total heat flux

While comparing the temperature of all the models we can see from the graph above that, the maximum value of temperature is found in base model i.e; 151.57ºC which is reduced in our proposed model and the value obtained is 130.84ºC. Similarly, on comparing total heat flux of all the models, the above graph shows that base model has minimum value of total heat flux i.e; 0.099 W/mm^2 whereas our proposed model enhances this value to 0.165W/mm^2.

6. CONCLUSION

This study significantly contributes to the field of automotive engineering by enhancing the understanding of disk brake rotor designs and their thermal and structural characteristics. Through computational analysis using ANSYS, it provides insights into the importance of heat management in braking systems and the impact of design modifications on brake performance. The research highlights the transformation of kinetic to thermal energy as a critical aspect of braking efficiency, underscoring the importance of proper brake design and maintenance. The classification and analysis of various braking systems demonstrate the evolution and specialization of brake technology. By conducting comparative analyses on different brake rotor models, the study offers practical solutions to improve safety and efficiency in automotive braking systems. The findings suggest that tailored rotor designs, optimized through computational methods, can significantly enhance brake performance, addressing the challenges of heat dissipation and structural integrity in modern vehicles. This research paves the way for further innovations in braking technology, potentially leading to safer and more efficient automobiles.

REFERENCES

[1] R. K. Reddy, 2019. Dynamic analysis of mechanical braking system, no. January.
[2] N. M. Ghazaly, I. Ahmed, and M. R. E.- Sharkawy, 2014. A Review of Automotive Brake Squeal Mechanisms A Review of Automotive Brake Squeal Mechanisms,.
[3] I. Hutchings and P. Shipway, 2017. Applications and case studies, 2nd ed. Elsevier Ltd.,.
[4] V. P. Sergienko, S. N. Bukharov, and A. V Kupreev, Noise and Vibration in Brake Systems of Vehicles. Part 1: Experimental Procedures, 2008. 29, 3, 234–241. doi: 10.3103/S1068366608030136.
[5] F. Ilie and A. Cristescu, 2022. Tribological Behavior of Friction Materials of a Disk-Brake Pad Braking System Affected by Structural Changes — A Review,.
[6] A. Papinniemi, J. C. S. Lai, and J. Zhao, 2002. Brake squeal: a literature review, 63, 391–400.
[7] M. D. Atkins, 2019. Flow behavior in radial vane disc brake rotors at low rotational speeds, doi: 10.1115/1.4042470.
[8] A. Afzal and M. A. Mujeebu, 2018. Thermo-Mechanical and Structural Performances of Automobile Disc Brakes: A Review of Numerical and Experimental Studies, Arch. Comput. Methods Eng., 0123456789, 18–20. doi: 10.1007/s11831-018-9279-y.
[9] P. S. Shanker, ScienceDirect ICMPC. 2018. A review on properties of conventional and metal matrix composite materials in manufacturing of disc brake, Mater. Today Proc., 5, 2, 5864–5869. doi: 10.1016/j.matpr.2017.12.184.
[10] W. Li, X. Yang, S. Wang, J. Xiao, and Q. Hou, 2021. Research and prospect of ceramics for automotive disc-brakes, Ceram. Int., 47, 8, 10442–10463. doi: 10.1016/j.ceramint.2020.12.206.
[11] S. Sarip, 2021. Thermal Analysis of Disc Brake Thermal Analysis of Disc Brake.
[12] D. K. Dhir, 2018. ScienceDirect Thermo-mechanical performance of automotive disc brakes, Mater. Today Proc., 5, 1, 1864–1871, doi: 10.1016/j.matpr.2017.11.287.
[13] S. E. Alam, Y. Vidhyadhar, P. Sharma, and A. Jain, 2020. Thermal Analysis of disc Brakes Rotor : A comparative Report Thermal Analysis of disc Brakes Rotor : A comparative Report, 4.
[14] C. B. Saiz, T. Ingrassia, V. Nigrelli, and V. Ricotta, 2015. Thermal stress analysis of different full and ventilated disc brakes, 34, 608–621. doi: 10.3221/IGF-ESIS.34.67.