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Design and Analysis of Ventilated Disc Brake by Using Different Materials: A Review

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Abstract: ***Disc rotor is component which is used in automotive vehicle wheels to apply brakes, the concept which works during brake is frictional resistance between pad and rotor. Due to frictional resistance the heat gets generated between disc and pad so, in order to reduce the effect of heat the rotor is designed as ventilated disc. The common material which is used to manufacture the disc rotor is Grey Cast Iron. The purpose of this review paper is to study the behavior and kinds of work has been done before on Disc Brake and based on this review paper we have decided to do structural analysis on disc brake rotor using different materials like GREY CAST IRON, TITANIUM, MAGNESIUM ALLOY, ALUMINUM ALLOY, and STRUCTURAL STEEL and then compare the results of different materials with conventional material (GREY CAST IRON) that is usually used in disc brake rotor. The analysis will be done by using CATIA for modeling and ANSYS WORKBENCH 18.0 for structural analysis.***

Based on previous research the objective of this review paper is "Design and analysis of ventilated disc brake by using different materials"

Keywords: Disc Rotor, Titanium, Grey Cast Iron, Ventilated, Titanium, Topology optimization

I. INTRODUCTION

Brakes are the most important safety parts in the vehicles. Brakes function to slow and stop the rotation of the wheel. To stop the wheel, braking pads are forced mechanically against the rotor or disc on both surfaces. They are compulsory for the safe operation of all vehicles. In short, brakes transform the kinetic energy of the car into heat energy, thus slowing its speed [1]. The main principal idea of braking is to incorporate the kinetic energy of the body and convert it into frictional energy, which generates heat, and the temperature is dissipated into the surroundings. [2] Brake fade is the reduction in stopping power that can occur after repeated or sustained application of brakes, especially in high load or High-speed conditions [3]. Disc brake consisting structural steel disc bolted to the wheel hub and a stationary housing which is known as caliper. The caliper is connected to some stationery part of the vehicle like the stub axle as is cast in two parts each part consists of a piston. In between each piston and the disc there is a frictional pad hold in position by detainments pins, spring plates [4].

To determine the temperature distribution in discs, it is necessary to solve the appropriate heat transfer equations. The solution of this problem depends on the physical conditions existing at the boundaries of the medium and on the conditions existing in the medium [5] noted that the heat transferred due to friction is

$q = \mu pv$

where μ is the friction coefficient, v is the sliding velocity of the disk at the point of contact and p is the contact pressure at the interface, q is the amount of heat generated by friction.

To stop the vehicle, friction material in the form of brake pads is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc [6-8]. Friction causes the disc brake and attached wheel to slow or stop. For the exposed region of the disk and brake pads, it is assumed that heat is exchanged with the environment through convection as well as radiation. Therefore, convection surface and radiation surface boundary condition are applied as:

$q1 = h \times A \times (To - Ts)$ And $q2 = \varepsilon \times \sigma \times A \times [(T0)^4 - (Ts)^4]$

where q1 is the heat dissipated from the rotor by convection,

q2 is the heat dissipated from the rotor by radiation,

h is the average heat transfer coefficient,

A is the area of the rotor in contact with the surroundings,

To is the surface temperature of disc brake rotor and Ts is the ambient temperature, ε is the emissivity of the rotor, σis the Stefan – Boltzmann constant.[9]

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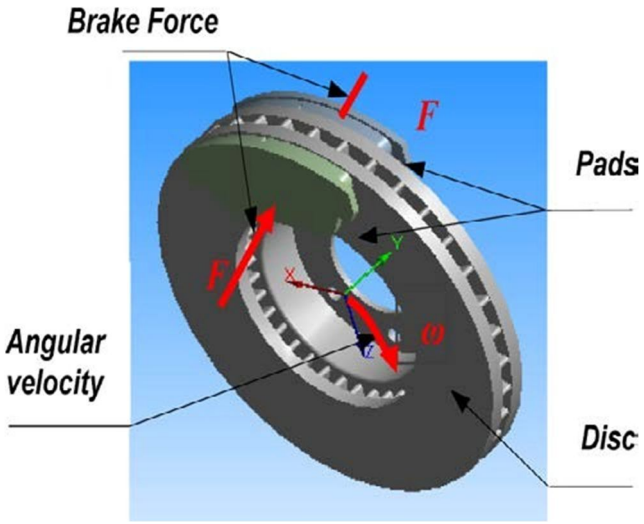


Figure 1.1 Schematic Diagram of Disc Brake

DISC BRAKE COMPONENTS

1) Caliper: The brake calipers have a two brake pads and wheel cylinder.
2) Brake pad: The pad is mostly made on the nonmetallic materials Eg. Ceramic materials.
3) Piston: It is used to push the brake pad by the flow of brake fluid.
4) Rotor or disc: It provides a smooth surface against which to face the brake pads, to slow or stop the vehicle.
5) Master cylinder: It's carries the brake fluid we apply the brake to supply to wheel cylinder.

II. LITERATURE REVIEW

The various researches have been study for the performance of the Disc brake rotor some of them are**:**

1) C. Radhakrishnan, Yokeswaran.K, Vengadeshprasadh.M, Vishnuhasan.A, Vimalraj.T , Velusamy.M, (2015)[1]

In this project author analyse the thermal behaviour of the ventilated brake disc with Titanium alloy (Ti 550) and conventional grey cast iron material in finite element software ANSYS WORKBENCH 14.0. Modelling of the disc brake rotor is done using SOLIDWORKS 2013.Finally a comparison has been made between conventional grey cast iron and Ti 550 materials and the best material for making disc brake have been suggested based on the magnitude of Von misses stresses, temperature distribution and deformation from the thermal analysis result.

After the comparison of results between Ti 550 alloy and grey cast iron material brake disc based on the wear resistance and thermal gradient properties, it is found that the heat dissipation and force created by these two materials Ti 550 alloy is best on the thermal analysis.

2) Challa Balaji Naga Sai Abhishikt , Balaji Ramachandran , Ganti Naga Alekhya (2020)[2]

In this paper the author have suggested that the braking system's efficiency should be at par with the engine to decelerate the car from a given speed within a less braking distance. The disc rotor and brake pads design and material while counting other impacting factors contribute to braking efficiency. The friction coefficient is abated by the brake discs overheat and to circumvent this issue, and the rotor disc should be adequately ventilated to allow maximum heat dissipation from the disc to the surroundings. The overheating of the disc rotor causes the surface to harden, making the brake pads challenging to seize them. By subsuming drilled contours on the rotor disc, the enhanced surface area aids in the rapid heat transfer from the rotor disc to the environment moderating the heat generated at the pad-disc interface. Anew drafted brake rotor discs with drilled contour and ventilated discs are model using SOLIDWORKS.

Static structural and thermal analysis performed with different disc materials using the finite element simulation software ANSYS. Based upon the temperature gradient, the heat dissipation obtained from the study, it is evident that the newly designed discs are significantly efficient, with longer brake spans and no abundant reduction in coefficient of friction of brake pads. A comparative study stated out for the various materials of the disc rotor.

3) A. S. Abrar Ahmed, V. Ayush Kumar, S. Gokul, P.Vijay (2020)[3]

The main objective of this paper is to propose a new automotive brake disc rotor design for BAJAJ PULSAR 150 which will reduce the total deformation and increase the maximum heat dissipation. Here various shapes of ventilated holes in brake disc rotor is designed using AUTODESK INVENTOR 2019. The inner and outer boundaries are preserved so that the changes are made only in the intermediate patterns between the boundaries, thus the models have same structural boundary limits. The static structural analysis and steady state thermal analysis of brake disc rotor is done using ANSYS 19, which 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, is carried out for static structural analysis to increase the accuracy of result. The best of the designed brake disc rotor is to be suggested based on the magnitude of von - misses stresses, deformation, temperature, total heat flux, and weight.

4) Abbas Mohammed Ismael (2018)[4]

The aim of this research as the following, during the brake operation the pads press to the tire disc, and as a result we will analyze the heat distribution on the discs by using SOLIDWORKS software program to get the best design for discs that used in this system and to do this We chose three types of disc rotors (1. Vented and Drilled, 2. Vented, 3.Solid). The FEM “Finite Element Method” is the best way to analyze the heat distribution. Analyzing the heat distribution of these three types will provide us a heat flux distribution too. The temperature in the disc brake is modeled with regard to the variation of a certain number of parameters such as the type of braking, the cooling model of the disc and the choice of disc material. The brake discs are made of cast iron with high carbon content. The contact surface of the disc receives an entering heat flux the model presents a 3D solid disc squeezed between two finite-width friction materials. The heat distribution in the vented and drilled type has a good performance from the others.

5) Pranay Dawne , Ruchika Saini (2022)[5]

The Braking systems is most important part in automobile industries. It is used to maintaining and controlling the speed of the vehicle. So it is important to find the best suited material, which can maintain the heat generation and sustain the other mechanical loading. In this paper authors have done study of maximum heat transfer for different materials (Structural Steel, Titanium Alloy, Copper Alloy, Magnesium Alloy and for the Aluminum Alloy) on the basis of Static structural and thermal analysis performed in the disk brake using the finite element simulation software ANSYS was investigated. This research shows comparison between Brake disc materials namely, Structural Steel, Titanium Alloy, Copper Alloy, Magnesium Alloy and for the Aluminum Alloy. The results were compared on the basis of Heat flux, Total Deformation, Stress, Strain and thermal behavior of materials. we can see that, maximum temperature variation comes in Titanium alloy disk is 100 °C to 89.173°C and minimum in Copper Alloy is 100°C to 99.315°C. In the case of heat flux maximum value obtained in Copper Alloy based disc which is 0.010974 W/mm2 and minimum in Titanium alloy which is 0.0099397 W/mm2 based disc. Structural Steel gives maximum value of Equivalent stress which is 493.37 Mpa and Titanium alloy gives minimum value of Equivalent stress which is 186.93 Mpa based disc as compare to other materials. The Magnesium Alloy material gives maximum deformation which is 0.21693 mm and the Titanium alloy material gives minimum deformation which is 0.077834 mm comparatively others. MagnesiumAlloy gives maximum value of Equivalent strain which is 0.0058711 mm/mm and Titanium alloy gives minimum value of Equivalent strain which is 0.0019476 mm/mm based disc as compare to other materials. And Titanium alloy, Structural steel made rotor disk give better heat dissipation results.

6) Pandya Nakul Amrish (2016)[6]

The purpose of this research is to analyze different types of disc brake rotors, which are commonly used in automobile industry and to propose a new design of brake rotor. Analysis of brake rotor includes Structural analysis and Steady state Thermal analysis for each design. A comparison between the existing brake rotors and proposed new design is carried out and based on the results the best design is found out by ANSYS software. On the basis of the analysis and the results, it is observed that that solid as well as the drilled rotor are structurally safe as the total maximum stress is within the ultimate stress limits for the material used which is gray cast iron. Also, the rotor can be equipped in a real time automobile as its total maximum deformation are 0.00113 mm and 0.000973 mm respectively for solid and drilled rotor. The temperature variation and heat flux is nearly the same for both rotors, however for the drilled rotor, maximum temperature and the overall heat flux is slightly lesser due to increased surface area for heat dissipation while braking due to the drilled holes. As a final conclusion and inference, it wouldn’t be wrong to say that drilled rotors have a better performance when compared to non-vented solid rotors due to reduced stress, strain, overall deformation and thermal stability.

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Hence, drilled rotors are generally used in performance cars like sports cars, ATV's and UTV's. However, drilled rotors are generally weak and at times difficult to manufacture and hence, usual commercial vehicles on roads prefer solid disc rotors.

7) N V S G SasiKiran, Madhava Reddy, Vikas Kumar, Siva Sasikanth, Venkateswara Rao (2022)[7]

A braking system is a safety gadget that gives safety to the passengers to lower the probability of a twist of fate. The braking control or deceleration of an automobile is carried both by the use of a drum brake machine or a brake disc device drum brake system is the conventional machine which an extended braking system results in the less braking efficiency whereas, the disc brake gadget is powerful in comparison to drum brake because it's having a shorter braking system. The main objective is to increase a brake disc rotor with specific profiles additionally it contains vent holes to grow its efficiency. At the same time, the Modelling of the brake disc rotor goes to be using SOLIDWORKS with the aid of taking the BAJAJ PULSAR 150 brake disc rotor dimensions as a reference. The heat dissipation from the brake disc rotor and additionally its capability of resisting structural loads state the efficiency of the design. The Numerical simulation like static structural and thermal analysis will be executed in ANSYS. Total deformation, equivalent strain, equivalent elastic stress, and aspect of protections are to be executed in structural analysis whereas thermal analysis, general warmness flux, and temperature may be executed. Topological optimization might be finished to the brake disc rotor if you want to reduce its weight which is indirectly answerable the increasing its effectiveness.

III. CONCLUSION

Based on the review of all the papers above it is found that many research has been done in disc brake rotor. As it is discussed above that the disc brake rotor subjected to both structural and thermal stresses so it is necessary to design the disc brake by considering both the effects. In one review paper the conventional material grey cast iron is compared with the other materials and it found that titanium alloy TI550 shown better results than grey cast iron.

In another paper work has been done by taking solid and drilled hole disc brake and author concluded that that solid as well as the drilled rotor are structurally safe as the total maximum stress is within the ultimate stress limits for the material used which is gray cast iron. Also, the rotor can be equipped in a real time automobile as its total maximum deformation are 0.00113 mm and 0.000973 mm respectively for solid and drilled rotor. The temperature variation and heat flux is nearly the same for both rotors, however for the drilled rotor, maximum temperature and the overall heat flux is slightly lesser due to increased surface area for heat dissipation while braking due to the drilled holes.

IV. FUTURE SCOPE

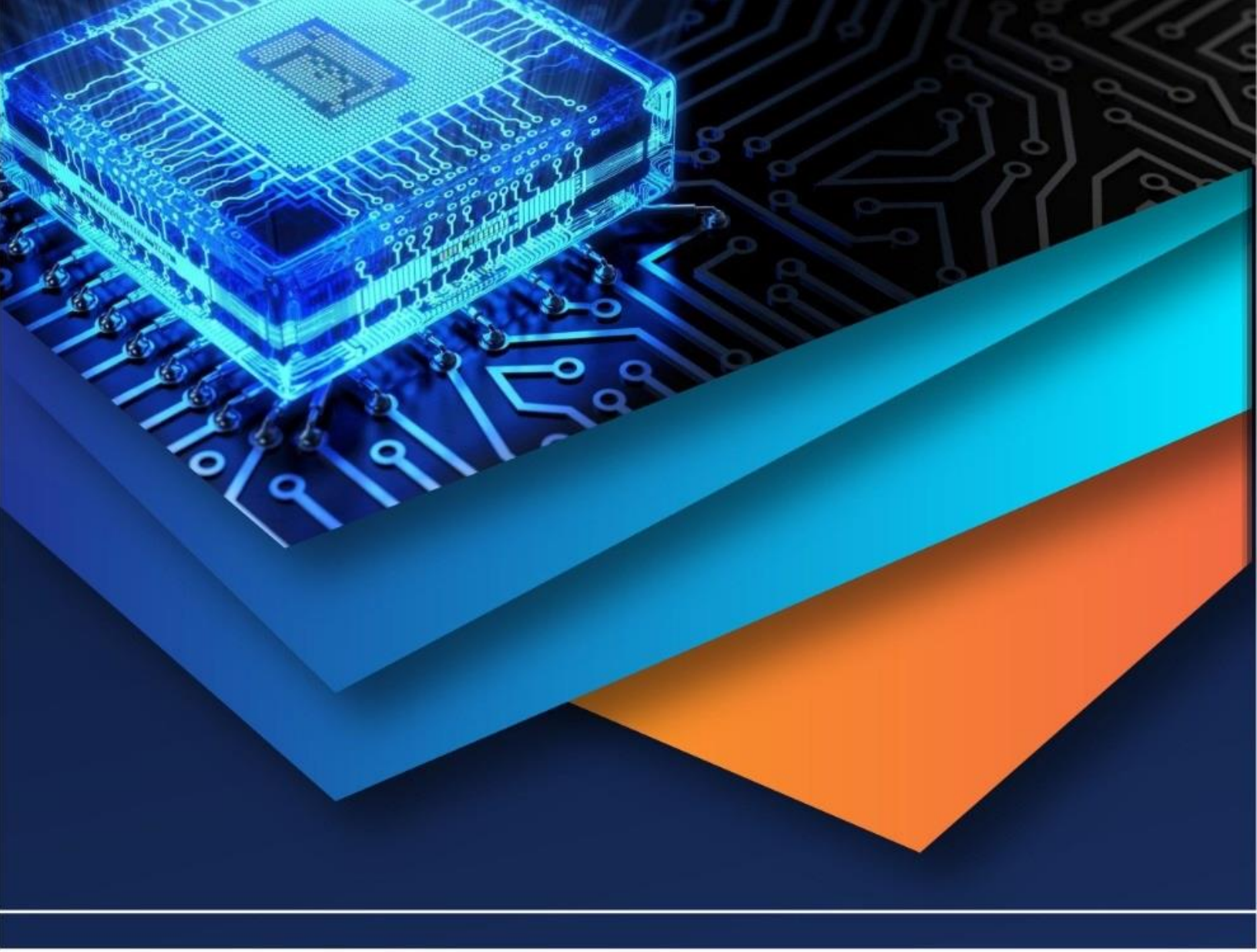
Based on the study of review papers it is found that in future, some work can be done by changing some design parameters of the disc and can also check disc with different materials and changed design. However some Work can also be done on weight optimization of disc brake rotor.

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