STRUCTURAL AND THERMAL ANALYSIS OF ROTOR DISC: A REVIEW

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***Abstract*: The Disc brake is a Mechanical device which is used to slow down or stop the vehicle. This is achieved by dissipating the kinetic energy possessed by the vehicle in the form of heat into the environment by the action of friction between disc rotor and brake pad. If the rotor gets too hot then It will not be able to dissipate enough heat and the brake will fail, this high temperature also increase the wear rate of brake pads, along with this high thermal stresses will get generated which can be fatal for the rotor. In this paper we will study the research papers published by researchers and will try to find out the progress of research in this area.**

***Keywords*: Disc brake,Rotor analysis, Static analysis, Thermal analysis, Ansys.**

I. INTRODUCTION

A disc brake is a type of brake that uses calipers to squeeze pairs of pads against a disc or rotor to create friction. This action retards the rotation of a shaft, such as a vehicle axle, either to reduce its rotational speed or to hold it stationary. The energy of motion is converted into waste heat which must be dispersed. The brake disc (or rotor) is the rotating part of a wheel's disc brake assembly, against which the brake pads are applied. The material is typically gray iron, a form of cast iron. The design of the discs varies somewhat. Some are simply solid, but others are hollowed out with fins or vanes joining together the disc's two contact surfaces (usually included as part of a casting process). The weight and power of the vehicle determines the need for ventilated discs.The "ventilated" disc design helps to dissipate the generated heat and is commonly used on the more-heavily loaded front discs. Under extreme conditions, such as descending a steep hill with a heavy load, or repeated high-speed decelerations, drum brakes would often fade and lose effectiveness. Compared with their counterpart, disc brakes would operate with less fade under the same conditions. An additional advantage of disc brakes is their linear relationship between brake torque and pad/rotor friction coefficient.
On Motorcycles: Motorcycle disc brakes have become increasingly sophisticated since their introduction in 1969 on the Honda CB750. Motorcycle discs are usually drilled and occasionally slotted, to help remove rain water.The front brake(s) provide most of the required deceleration, while the rear brake serves mainly as to "balance" the motorcycle during braking. A modern sports bike will typically have twin front discs of large diameter, but only a very much smaller single rear disc.
On Bicycles: Mountain bike disc brakes range from simple, mechanical (cable) systems, too expensive and
powerful, 6-pot (piston) hydraulic disc systems, commonly used on downhill racing bikes. Improved technology has seen the creation of the first vented discs for use on mountain bikes, similar to those on cars, introduced to help avoid heat fade on fast alpine descents. Discs are thin, often about 2 mm.Some use a two-piece floating disc style, others use a floating caliper, other pads that float in the caliper, and some use one moving pad that makes the caliper slide on its mounts, pulling the other pad into contact with the disc.
On other vehicles: Disc brakes are increasingly used on very large and heavy road vehicles, where previously large drum brakes were nearly universal. One reason is the disc's lack of self-assist makes brake force much more predictable, so peak brake force can be raised without more risk of braking-induced steering or jackknife on articulated vehicles. For these reasons, a heavy truck with disc brakes can stop in about 120% the distance of a passenger car, but with drums stopping takes about 150% the distance. In Europe, stopping distance regulations essentially require disc brakes for heavy vehicles. Yet larger discs are used for railroads and some airplanes. Passenger rail cars and light rail often use disc brakes outboard of the wheels, which helps ensure a free flow of cooling air.

II. LITERATURE REVIEW

1. Janvijay Pateriya, Raj Kumar Yadav, Vikas Mukhraiya and Pankaj Singh

-Brake Disc Analysis With The Help Of Ansys Software

This paper explains the effect of thermal and structural loads on a solid disc brake rotor. The model was created in 3D modeling software and then it was imported to Ansys Workbench for simulation. In a single model, different materials were tested such as Cast Iron(Alloy), Titanium Alloy,AL-NI-CO(Alloy),Structural Steel(Alloy). The table below shows the results obtained after the analysis.

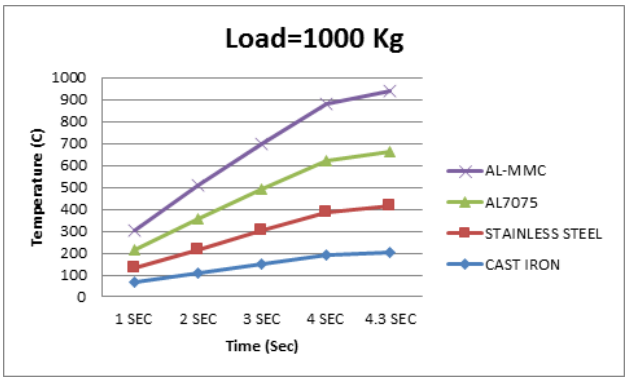
Properties	Cast Iron (ALLOY)	Titanium (ALLOY)	AL-NI-CO (ALLOY)	Structural Steel (ALLOY)
Total (Mm) Deformation	0.0151	0.025	0.012	0.017
Equivalent Stress (Mpa)	75.48	73.725	73.099	74.123
Equivalent Elastic Strain	0.00047	0.00078	0.00031	0.00037
Factor Of Safety	3.71	12.613	9.5	3.3
Temperature (Tf) °C	85	75.26	87.5	80
Heat Flux (W/Mm^2)	0.4	0.188	0.161	0.570
Weight (Kg)	3.00	1.5	2.84	3.2

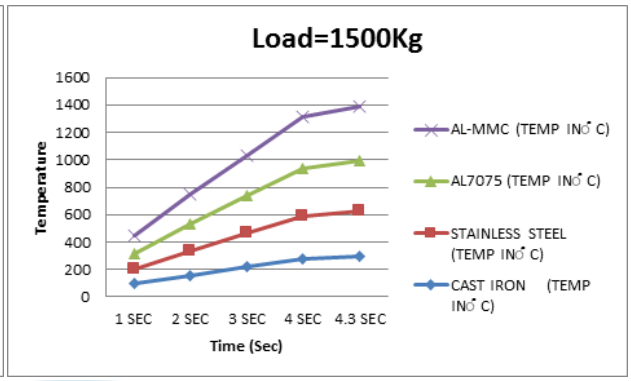
This table compares material al-ni-co and material titanium with material CAST IRON in terms of maximum von misses Stress, maximum total deformation and weight reduction.Finally we calculate good material through total deformation, stress, strain, weight & by some other property for brake disc. al-ni-co alloy & titanium alloy is a good material for brake disc from compare to cast iron & structural steel.

2.Baskara Sethupathi P., Muthuvel A., Prakash N., Stanly Wilson Louis

- Numerical Analysis of a Rotor Disc for Optimization of the Disc Materials.

The objective of this research is to define thermal performance on disc brake models Thermal performance is a key factor which is studied using the model in Finite Element Analysis simulations. Ultimately a design method for brakes suitable for use on any car-sized vehicle was used from previous analysis.The design requirement, including reducing the thickness would affect the temperature distribution and increase stress at the critical area. Based on the relationship obtained between rotor weight, thickness,undercut effect and offset between hat and friction ring,criteria have been established for designing brake discs in a vehicle braking.





It is seen that cast iron is more suitable and more economic.

3.K.Sowjanya, S.Suresh

-Structural Analysis of Disc Brake Rotor

This paper deals with the analysis of Disc Brake.A Brake is a device by means of which artificial frictional resistance is applied to moving machine member, in order to stop the motion of a machine. Disc brake is usually made of Cast iron, so it is being selected for Investigating the effect of strength variations on the predicted stress distributions. Aluminium MetalMatrix Composite materials are selected and analysed.The results are compared with existing disc rotor.The model of Disc brake is developed by using Solid modeling software Pro/E (Creo- Parametric 1.0).Further Static Analysis is done by using ANSYS Workbench. Structural Analysis is done to determine the Deflection, Normal Stress ,Vonmises stress.

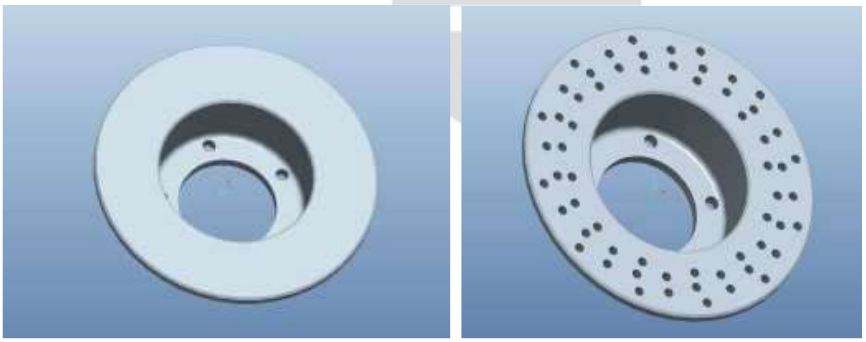
Material	Deformation	Normal stress	Vonmises stress
CI	0.35193	5.8095	50.334
AlMMC1	0.35229	64.812	211.98
AlMMC2	0.36648	65.345	566.7

Comparing the different results obtained from the analysis, it is concluded that Cast Iron is the best possible combination for the present application.

4.Ameer Fareed Basha Shaik, Ch.Lakshmi Srinivas

- Structural And Thermal Analysis Of Disc Brake With And Without Crossdrilled Rotar Of Race Car

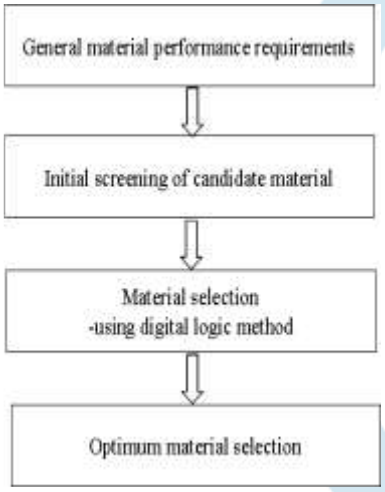
This paper studies about the model of a disc brake used in Honda Civic. Coupled field analysis (Structural+Thermal) is done on the disc brake. The materials used are Cast Iron. Analysis is also done by changing the design of disc brake. Actual disc brake has no holes; design is changed by giving holes in the disc brake for more heat dissipation. Modeling is done in Catia and Analysis is done in ANSYS.



The detail review of this paper will lead one to understand that essentially a new conceptual caliper design was proposed to decrease the thermal deformation at high temperatures. The modular caliper is an assembly unit made up of simple and easy to manufacture parts. The machining cost will be reduced as compared with the monoblock unit. The Existing caliper was first analyzed at cold working conditions without taking into account the effects of thermal expansion. The maximum stress was lower for Al 2219 than the Al 6061 brake caliper. The existing brake was analyzed at 300ºF. The caliper showed high

thermal stresses and displacement as compared with the previous case this is due to the thermal expansion of caliper body The modular design was analyzed without considering the effects of thermal expansion. This is done to study the amount of deformation due to tangential Force and pressure loading. These results were used to study the increase in deformation in the caliper at high temperatures. The modular brake was then analyzed using a nodal temperature of 300ºF. The displacement increased as compared with the previous case. This is due to the thermal expansion of the individual parts in the assembly.Since race cars brakes always operate at high temperature the thermal deformation /displacement results are important. The thermal displacement in the modular caliper is lower than the conventional caliper by 8.56 %.

5 M.A. Maleque, S.Dyuti and M.M. Rahman (Member, IAENG)
-Material Selection Method in Design of Automotive Brake Disc
The aim of this paper is to develop the material selection method and select the optimum material for the application of brake disc system emphasizing on the substitution of this cast iron by any other lightweight material. Two methods are introduced for the selection of materials, such as cost per unit property and digital logic methods. Material performance requirements were analyzed and alternative solutions were evaluated among cast iron, aluminium alloy, titanium alloy, ceramics and composites. Mechanical properties including compressive strength, friction coefficient, wear resistance, thermal conductivity and specific gravity as well as cost, were used as the key parameters in the material selection stages. The analysis led to aluminium metal matrix composite as the most appropriate material for brake disc system.



Cost and figure of merit of candidate materials

Material	Relative Cost	Performance Index (γ)	Figure of Merit	Rank
GCI	1	81.0	11.25	2
Ti-6Al-4V	20	49.5	0.56	5
TMC	20.5	56.0	0.58	4
AMC 1	2.7	79.0	10.84	3
AMC 2	2.6	88.6	12.17	1

Conclusion -The material selection methods for the design and application of automotive brake disc are developed. Functions properties of the brake discs or rotors were considered for the initial screening of the candidate materials using Ashby's materials selection chart. The digital logic method showed the highest performance indexfor AMC 2 material and identified as an optimum material among the candidate materials for brake disc In the digital logic method, the friction coefficient and density were considered twice for determining the performance index and the cost of unit property. This procedure could have overemphasized their effects on the final selection. This could be justifiable in this case as higher friction coefficient and lower density are advantageous from the technical and economical point of view for this type of application.

III. CONCLUSION
From the above literature survey we find that there are many researches done on disc brake and material choosen for analysis are cast iron, aluminium alloy, aluminium metal matrix,composite materials and titanium alloys. The brakes were being tested for structural and thermal analysis. Composites have shown very good strength as compared to pure materials whereas cast iron came out to be the most economical material. In current scenario weight reduction plays very important role in designing process and hence the industry is shifting towards composites such as silicon arbide and AMMC which shows good strength and wear resistance capabilities. If design is concerned than vented or crossdrilled brake disc rotor will surely have advantage over solid disc rotor.

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