Modelling and Simulation of Automotive car disc brake system

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Abstract : One of the most essential and crucial safety features in contemporary automobiles is the braking system. The wheels' kinetic energy is absorbed by the brake and released as heat energy into the atmosphere around it. It causes the car to slow down or halt. As a result of the considerable force placed on it when the brake is applied, the disc brake may have structural problems as well as wear. For improved performance, it is thus advised to pick low stress materials based on structural, stress, and thermal analyses. The goal of this study is to model and analyse disc brake stress concentration, structural deformation, and thermal gradient.. In this case, the analysis of the disc brake is carried out by ANSYS workbench R 20.1 and Solidworks is used for design.

Keywords: Disc Brake, FEA (Finite Element Analysis), ANSYS workbench R 20.1, Solidworks

1. Introduction

Due to the varying conditions of street and road traffic, it is very necessary for a vehicle to possess a slowing mechanism so that the speed of the vehicle can be reduced and can be stopped if destination is reached. The fundamental rule utilized in slowing mechanisms is to change over the motor power of a vehicle to another type of power. For instance, in contact slowing down category, the energy is changed over into heat, and in the category of regenerative slowing down, the energy is changed over into power or compacted air and so on[1]. At the time of slowing down activity of a vehicle, not the entire dynamic energy is changed over to ideal structure, for example in erosion slowing down some energy may be disseminated as vibrations. In a concise portrayal of various slowing mechanisms utilized in a vehicle is given.

Objectives:

i. To model and analyse of disc brake stress concentration, structural deformation, and thermal gradient..
ii. To analysis of the disc brake is carried out by ANSYS workbench and Solidworks is used for design.
iii. For improved performance, it is thus advised to pick low stress materials based on structural, stress, and thermal analyses

Problem Statement: In automobile sector brake system plays an important role due to these faced following problems.

i. Kinetic energy is absorbed by the disc brake and released as heat energy into the atmosphere surroundings.
ii. Due to force placed on the disc brake may have structural problems as wear and tear?

1.1. Disc Brake

A circle brake is made up of a stationary housing known as a calliper and a cast iron plate that is angled toward the centre of the wheel. The calliper is connected to a fixed component of the car, such as the hub packaging or the stub pivot, and is shaped like a cross with two halves, each of which has a cylinder in it. Every cylinder and circular have a rubbing cushion in the centre that is held firmly in place by retaining pins, spring plates, and other mechanisms. These portions are punctured by the calliper so that the liquid may enter or exit each lodging. Additionally, one of the portions is connected to death. Each chamber has an elastic locking ring that connects the chamber to the cylinder [2].

Two kind of grinding brakes, drum brakes and plate brakes, are generally utilized. Plate brakes when contrasted with drum brakes cool quicker, because of bigger cleared region and generally higher openness to wind current, and show self ability to clean because of radial powers. Because of these reasons and a few different benefits circle brakes have turned into the all inclusive. Decision for front brakes on vehicles and are likewise expected to rule the truck market soon. This audit paper comprises of five significant areas: Presentation, Tribology, Circle brakes, Functional problems and Ends [4]. In Circle brakes segment, various pieces of a plate stopping mechanism are introduced. Different designs of material and parts are likewise examined. In Tribology segment, modifications occurring at the connection point are portrayed. In Functional problems part, the problems connected with plate brakes experienced when breaking, for example blur and commotion will be depicted. At, 'All in all' part, a few finishing up comments are given.

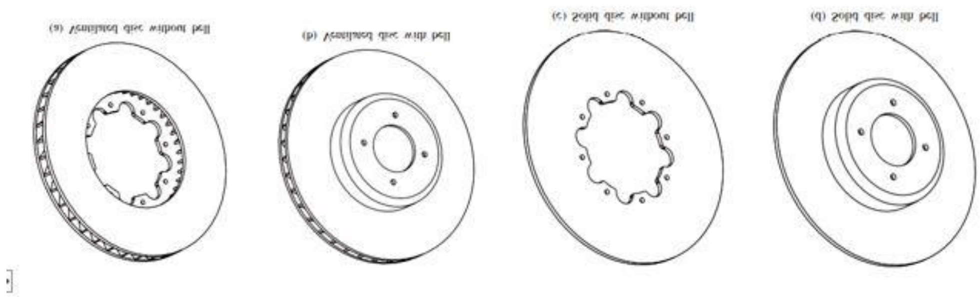


Fig.1 Solid disc and Ventilated disc with and without bell

1.2. Brake Plates

Also called brake rotor, is attached to the pivot, to turns as a speed of the wheel. Reducing the force of a circle that is still in the air pace at mechanical energy is transferred entirely turns with thermal shocks due to friction at the cushion and the plate [5]. Intensity must be distributed as quickly as possible for a brake plan to be effective; otherwise, the plate's temperature may increase and affect the circle brake's performance. Therefore, pass of air holes is supplied in the brake circles, it raises the cooling effect, to obtain an excellent presentation in requested applications. Two kinds of brake plates might be distinguished:

- Solid brake plates
- Ventilated brake plates

High strength brake plate is the easiest properties with compacts of a introverted strong circle. In a pool ventilated plates or support points or divide in to two segments circles and clear an entry to the air to stream, those brake circles increase the cooling rate well down the optimal result is low surface body temperature, it may demised the gamble of stop sleeves brake scratch[6]. However assists in reduced with wearing of the disc and cushion. Both of these plans are developed regardless of a mounting chime.

The bracket ringer to separate from the erosion surface with hinge and the surface area with circle more cooling the manner of assists with the course of wheel more temperature procedure to give very down, that it could be the two kinds of circles

A mounting ringer builds the separation from the erosion surface to pivot and the surface region of the circle which further develops cooling [3] and in this manner it assists with shielding the wheel course from the high temperature produced due to slowing down activity. A schematic portrayal of these two kinds of circles is given in figure 2.

1.3. Materials

The material often used for braking circles is dim cast iron with a mostly pearlitic network. Its outstanding cast and machinability, strong warm conductivity, high intensity limit, protection against brake blur, and reduced cost make it a great material for plates [7]. In order to reduce the overall load of the vehicle and ultimately increase fuel efficiency, there is a corporate interest in using lighter materials for the plate. The brake circles are crucial to the vehicle's unspring mass, therefore reducing them also improves driving comfort. This is another rationale for using lighter plate.

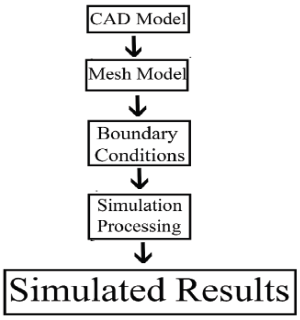
2. Literature review

A clear comparison is made between the results from the tables on the basis of each domain, the DISC 2,4,5,6 is found to deform in a comparatively higher value on applying the same load. The DISC 2,4,5,6 takes up a nominally higher Von-misses stress, comparatively nominal rise in temperature, nominal heat flux, with a slight increase in weight [8]. Thus, the DISC 3 is found to deform in a minimum value on applying the same load. The DISC 3 takes up a nominal Von - misses stress, comparatively nominal rise in temperature, nominal heat flux, with a better weight reduction [9,10]

The figure number and caption should be typed below the illustration in 8 pt and left justified [***Note:*** one-line captions of length less than column width (or full typesetting width or oblong) centered]. Artwork has no text along the side of it in the main body of the text. However, if two images fit next to each other, these may be placed next to each other to save space. For example, see Fig. 1.

3. Methodology

Properties of Air flow change considerably based on the arrangement of under body and shape by which the component exist. We make utilization of mean coefficient of heat transfer that is estimated from the known cooling factor with the help of an iteration methodology for the sake of executing the thermal oriented investigation.



ITEM	Values
Diameter of the Disc	298mm
Automobile height	68 mm
Size of pad	114*78*16
Top Speed of Automobile	160 mph
Effective Radius of Rotor	Rr 110 mm
Specific heat and Weight of the Disc	Cp 450 Jkg-1k -1 & 5kg
Disc Thickness and Centre	24 mm & Diameter 98 mm

Followed by the declaration of the physical properties of solid as well as the fluid, we consider the below said transient situation for the sake of determining the field of temperature in the brake of the disc at the time of braking stage.

- Incremental time= 0.01 (S) Braking time= 3.5 (S) Initial time = 0 (S)

It is a numerical technique for finding the approximate solutions to boundary value problems for partial differential equations. It uses subdivision of a whole problem domain into simpler part, called finite elements and solve the problem by minimizing an associated error function.

It divides the domain into a group of sub domain; every sub domain is represented by a set of element equations of the original domain.

The solver existing in the ANSYS CFX instantaneously estimates coefficient heat transfer prevailing in the boundary wall as shown in the following figure.

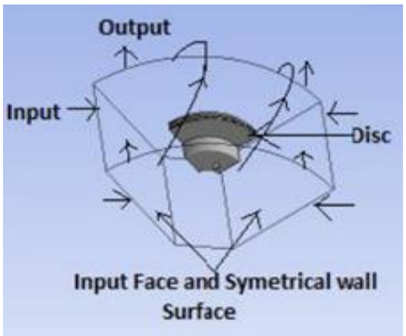


Fig.2. Depicts Disc Brake CFD prototype

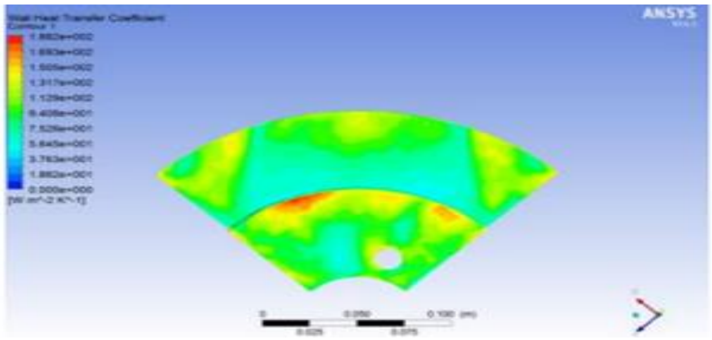


Fig.3. Depicts coefficient of Heat Transfer prevailing on the Disc Brake wall

Structural Analysis:

The below Figure depicts the disc brake meshed proto type for Structural investigation operation. For the sake of investigation, the messing of Ventilated disc brake was done by utilizing surface mesher of the triangular nature. The count of elements utilized in it is 28,042and that of the count of Nodes are 43,161. Thus, the proto type is mashed followed by analysis of it to get the accurate and detailed outcome of the stress of the contact surface.

Thermal Analysis:

The below Figure 4, depicts the disc brake meshed prototype for Thermal investigation operation. For the sake of investigation, the messing of Ventilated disc brake was done by utilizing the surface mesher of the triangular nature. The count of elements utilized in it is 65,016and that of the count of Nodes are 95,189. The prototype is mashed followed by analysis of it to get the detailed outcome of contact area. This is crucial since in this area, the temperature increases very considerably.

Loading and Boundary Condition:

For thermal analysis, the temperature distribution depends upon the heat flux entering the disc through both sides of the disc and wall heat transfer coefficient. For analysis the initial and boundary conditions are introduced in the transient thermal nodule of ANSYS WORKBENCH. The conditions for numerical analysis are as follows:

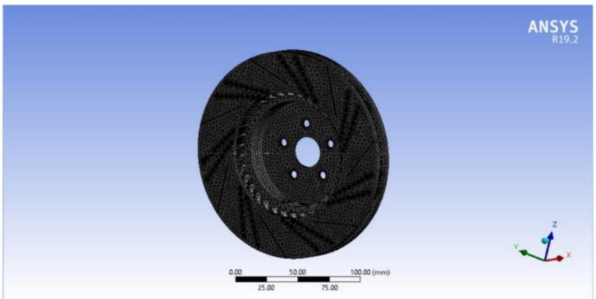


Fig.4. Meshing

Number of Steps	180
Current Step Number	1
Step End Time	1s
Auto Time Stepping	off
Define By	Time
Time Step	0.25 sec
Time Integration	on
Initial temperature of disc	65^0C
Pressure Applied on Both surface	1Mpa
Rotational speed of disc	44.91 rad/s

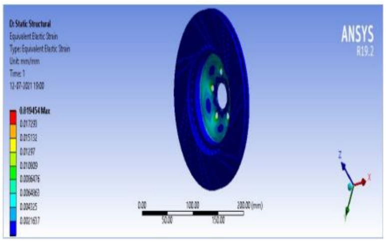
For structural analysis, temperature and corresponding stress in disc brake vary under freeway driving conditions. For analysis the initial and boundary condition are introduced in structural module of ANSYS workbench. Initial and boundary conditions area as follow.

4. Results and Discussions

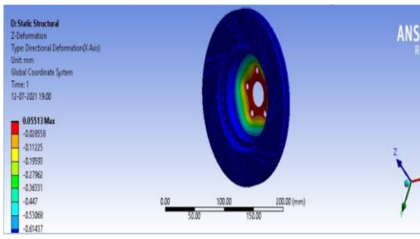
The Brake system model considering all the design parameters was done. A typical vehicle having brake system with disc brake was taken up for simulation. The response time of the system and the transient torque with disc brake were carried out. The same layout on replacing with an equivalent disc brake shows better torque characteristics. The brake system model was flexible enough to study the role of individual valves in system response. Apart from this the model can be further expanded for modeling and simulation of brake system layout. This approach will significantly reduce the overall system design lead time when compared to the conventional method.

4.1. Carbon

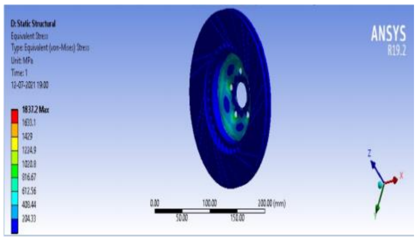
S. No.	Parameter	Maximum value	Minimum value
1	Equivalent Elastic Strain	2.3716e-006 mm/mm	1.9454e-002 mm/mm
2	Directional Deformation (X Axis)	-0.69806 mm	5.513e-002 mm
3	Equivalent (Von-Mises) Stress	0.21828 MPa	1837.2 MPa
4	Total heat flux	8.4439e-011W/mm²	6.7685e-003 W/mm²
5	Total Deformation	0 mm	0.7019 mm
6	Temperature distributions	89.013 °C	100. °C



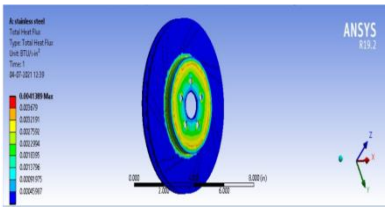
Elastic Strain



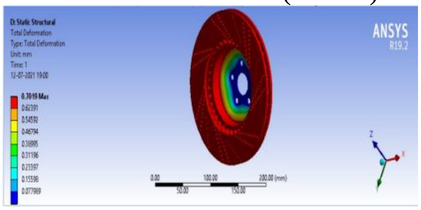
Directional Deformation (X-Axis)



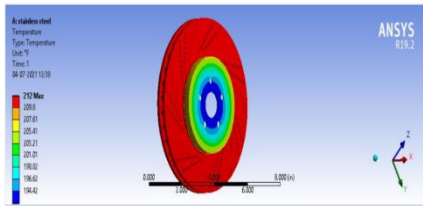
Von-mises Stress



Total Heat Flux

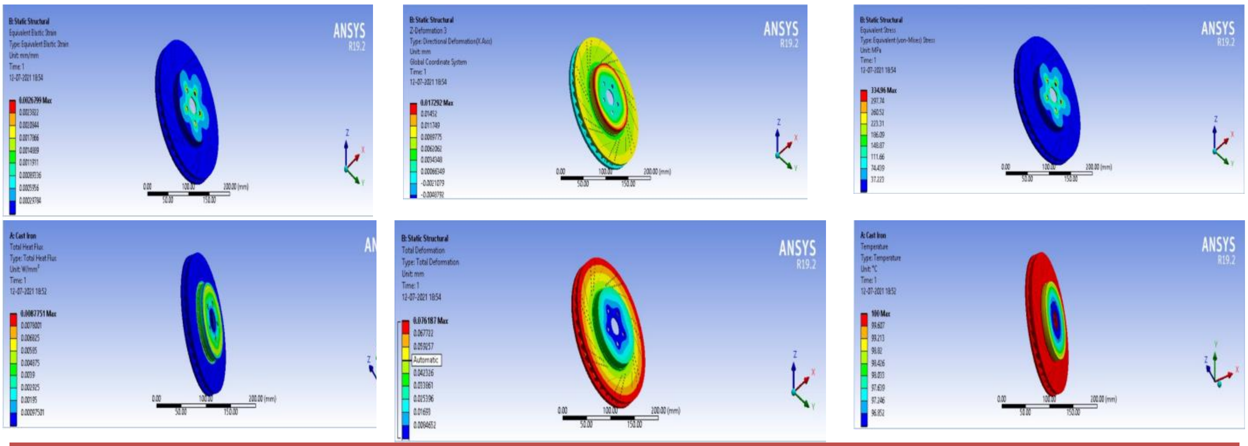


Total Deformation



Temperature Distributions

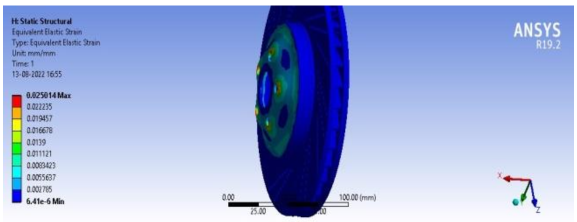
4.2. Cast Iron

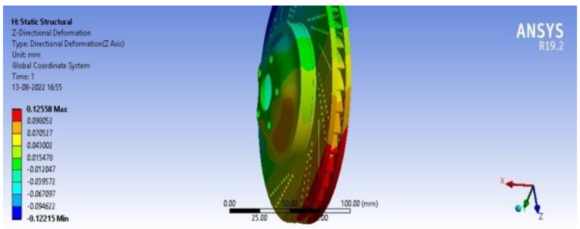


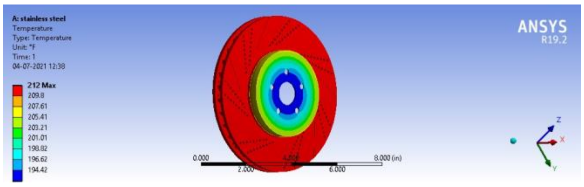
S. No.	Parameter	Minimum value	Maximum value
1	Equivalent Elastic Strain	7.4275e-008 mm/mm	2.6799e-003 mm/mm
2	Directional Deformation (X Axis)	-7.6506e-003 mm	1.7292e-002 mm
3	Equivalent (Von-Mises) Stress	5.9178e-003 MPa	334.96 MPa
4	Total heat flux	4.271e-011 W/mm²	8.7751e-003 W/mm²
5	Total Deformation	0 mm	7.6187e-002 mm
6	Temperature distributions	96.459 °C	100. °C

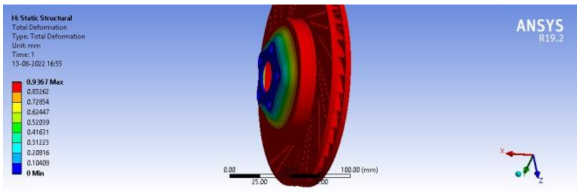
4.3. Stainless Steel

S. No.	Parameter	Minimum value	Maximum value
1	Equivalent Elastic Strain	1.0873e-002 mm/mm	1.617e-004mm/mm
2	Directional Deformation (X Axis)	2.7823e-002mm	-0.32561mm
3	Equivalent (Von-Mises) Stress	2065.6MPa	26.133MPa
4	Total heat flux	6.7685e-003W/mm²	1.2145e-004 W/mm²
5	Total Deformation	0 mm	0.35604mm
6	Temperature distributions	89.013 °C	100. °C



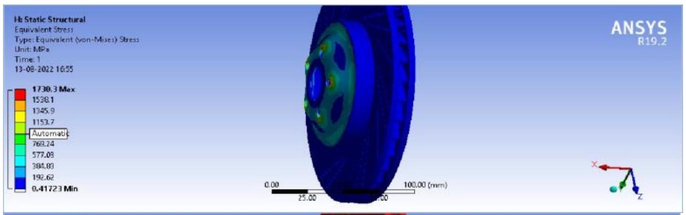


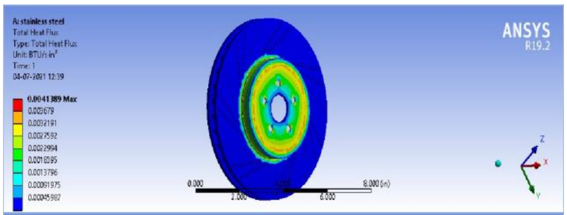


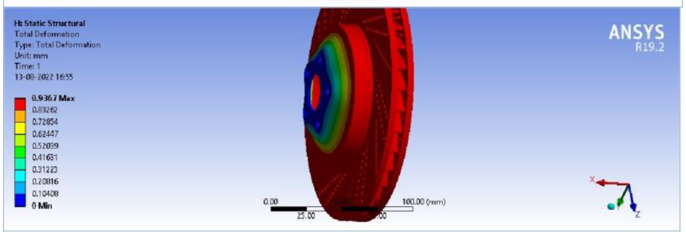


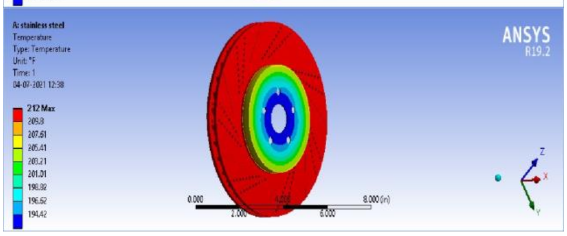
4.4. Aluminium Alloy-6262 T-9

S. No.	Parameter	Minimum value	Maximum value
1	Equivalent Elastic Strain	6.41e-006 mm/mm	2.5014e-002mm/mm
2	Directional Deformation (X Axis)	-0.93457 mm	7.4332e-002mm
3	Equivalent (Von-Mises) Stress	0.41723MPa	1730.3MPa
4	Total heat flux	9.1229e-011 W/mm²	7.3465e-003W/mm²
5	Total Deformation	0 mm	0.9367mm
6	Temperature distributions	98.894°C	100. °C









Conclusion

The transient thermal analysis of Disc brakes in brake applications has been per-formed. It is observed that the stainless steel can provide better brake performance than others from deformation point of view as we know stainless steel has 0.7019 mm while cast iron has 7.6187e-002 mm. Cast iron provides better performance from stress point of view. The present study can provide a useful de-sign tool and improve the brake performance of Disc brake system. The values obtained from the analysis are less than their allowable values. Hence the brake Disc design is safe based on the strength and rigidity criteria.

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