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Thermal Analysis of a Disc

Ratnajeet Wadile[1], Dr. Raghvendra Upadhyay[2]
[1]*Mechatronics Undergraduate,* [2]*Associate Professor, Terna Engineering College, University of Mumbai*

Abstract: ***The disk brakes are special mechanized parts in a vehicle attached with the tires to help reduce the velocity of the vehicle. As the brake pads caused friction with the disc brakes, there is a temperature rise. Due to this there are great chances of disc brake's failure if temperature rises above some permissible limit. Solidworks and ANSYS are the design and analysis tools which are used to accomplish this project. The disc brake was designed using Solidworks and it was analysed in ANSYS workbench. The main aim of this project is to analyse two-disc brakes manufactured with different materials to compare their properties and select one with most benefits.***

Keywords: ANSYS, FEA, Disc brake, Thermal analysis, braking system, Radiation.

I. INTRODUCTION

The braking systems in vehicles have been improving with time. The main function of a brake is to decrease the linear velocity by decreasing the angular velocity of tyres. This gives more stability and control to the vehicle. The decrease in velocity occurs due to the frictional force taking place between the brake pad and the disc brake. According to thermodynamics, this kinetic energy is converted into Thermal energy during this process. This generated temperature is then dissipated into the surrounding. This heat dissipation takes place through convection and radiation.

II. DISC BRAKE

A disc brake consists of brake pads, brake disc motor, and a calliper. Two brake pads are aligned parallel to each other with a disc brake place between them. The disc brake is fixed with the tires with the help of nut and bolts. It works on a hydraulic system, which, when pressed, activates the hydraulic system which presses the brake pads against the disc. This mechanism allows the disc to slow down as brake pads exerts opposing torque on the disc, decreasing speed of the vehicle.

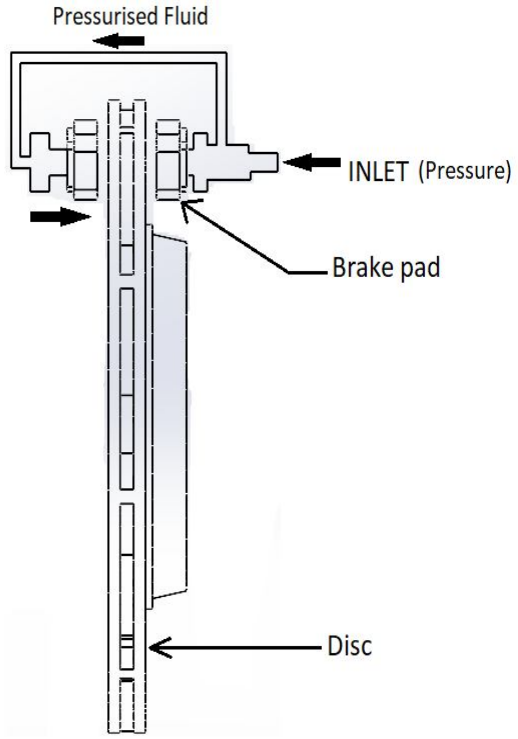

Fig.1 Representation of a disc brake

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A. Braking System

Brakes are the vital parts of any automobile. It generates required friction in the tires to discontinue their motion, in order to stop the movement of the vehicle. The brakes are able to perform this task as they absorb the kinetic energy the tires have and convert them into thermal energy, which is dissipated in the form of heat.

The brakes should be sturdy enough to stop the vehicle within minimum distance whenever needed. As brakes are usually used parts, they should have maximum anti-wear capabilities for long lasting and better performance.

There are three main types of brakes based on their operations.

1) *Hydraulic Brakes:* Hydraulic brakes work with the help of fluid reservoirs, which, applies the pressure on the brake pads, when pressed.
2) *Electric Brakes:* Electric brakes consist of armature, a field coil and a hub. When the brake pedal is pressed, an electric impulse is sent to the field coil, which acts as a magnet and attracts the armature and the hub towards itself, generating friction. That friction causes the velocity of the vehicle to go down.
3) *Mechanical Brakes:* This is a totally mechanical brake system which works with the help of spring and brake shoes. The brake shoes present in the tires expands whenever the brake pedal is pressed. This expansion of brake shoes causes friction reducing the velocity.

B. Heat Transfer in the Brake

The main and the foremost reason of causing heat in the brakes is friction. The whole disc is at different temperatures, while in use. According to the second law of thermodynamics heat is generated while braking. This heat gets transmitted from higher temperatures to lower temperatures to maintain the equilibrium. This heat transfer causes because of;

1) *Conduction:* It is the transmission of heat through minute particle present in the material, which consists of molecules, atoms, and electrons. They collide internally to transmit heat from on particle to another. The equation of the conduction is known as Fourier's law, which states that, the heat flow per unit area is proportional to the normal temperature gradient, where Thermal conductivity is proportionality constant.

$$q_x = -k\frac{dT}{dx}.$$

Where, q = heat flux, [W];
k = thermal conductivity, [W/(mK)]
dT/dx = Temperature gradient

2) *Convection:* It is the transfer of high temperature material to low temperature through the flow of fluid like, air or water.

$$q = hA\,dT$$

Where, q = heat transfer rate
h = convection heat transfer coefficient
A = exposed surface area
dT = temperature difference

III. FINITE ELEMENT ANALYSIS

Finite Element Analysis (FEA) is a computation method to calculate how a product reacts to the real-life forces acted on it. We can calculate the heat flow through a particular object, along with those other forces like vibration, aerodynamic forces, etc. In general, it will anticipate the behavior of the object in real=life conditions before using it.

To analyze the disc brake 'ANSYS Workbench R19' is used. In which a braking pressure of 1MPa is applied to simulate the behavior of the disc brake in real conditions. The design of the brake is accomplished using 'Solidworks 2021'. The disc has an outer diameter of 235 mm. The design was saved in ". igs" file, which is supported by ANSYS Workbench.

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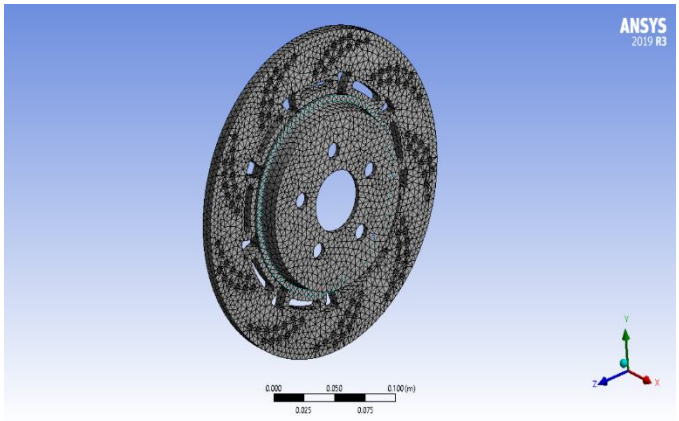

Fig.2 Meshing of the disc brake

A. Design of the Disc Brake

The disc brake is designed with the outer diameter as 235mm. The tool used to design the disc brake is "Solidworks". Some slots were place on the disc for ventilation purpose, which will be an added benefit for its life. The designed brake was saved in ". igs" file, which was then used in ANSYS Workbench for further analysis.

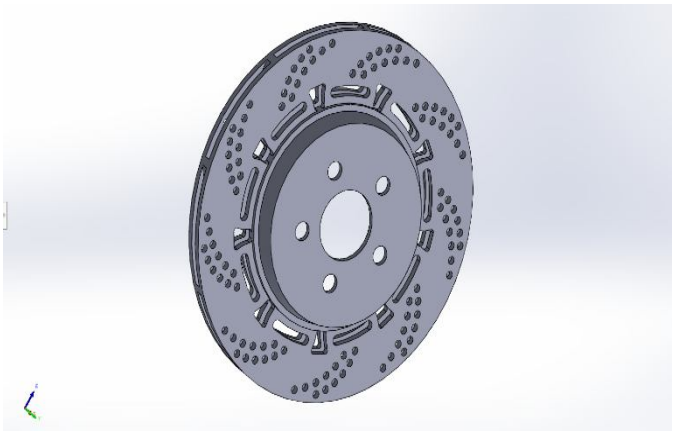

Fig.3 Design of the disc brake

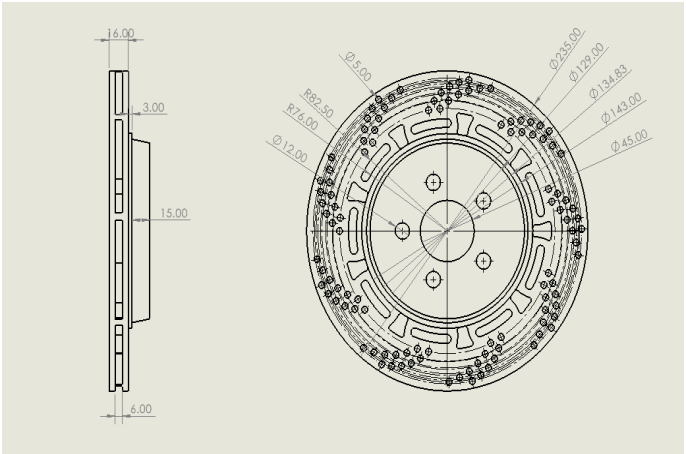

Fig.4 Dimensions of the disc brake

B. Structural Analysis

In this, the central part of the disc is kept fixed and a pressure of 1MPa is applied on the outer area, on both the sides. The following figure shows total deformation of the disc under applied conditions.

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C. Operating Conditions

Angular velocity (rad/sec)	100
Braking time (sec.)	7
Hydraulic Pressure (MPa)	1

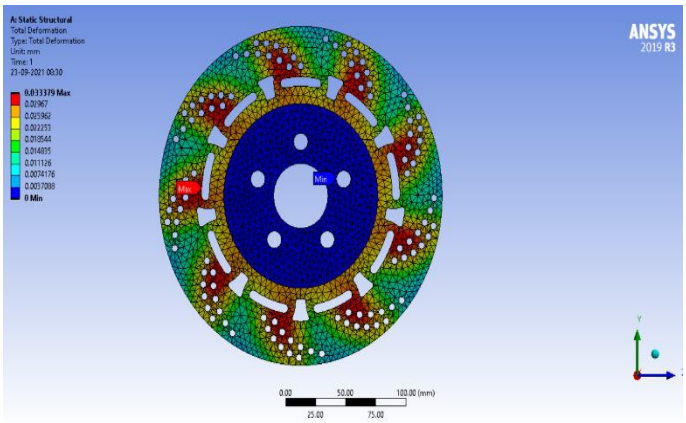

Fig.5 Structural analysis of the disc

D. Boundary Conditions

1) Heat Flux: Considering the width of the brake pad, heat flux is applied on both of the surfaces of the disc brake.

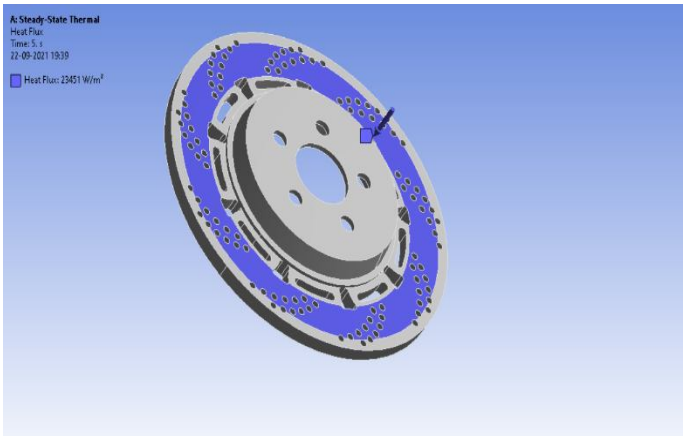

Fig.6 Heat flux applied to the disc

2) Convection

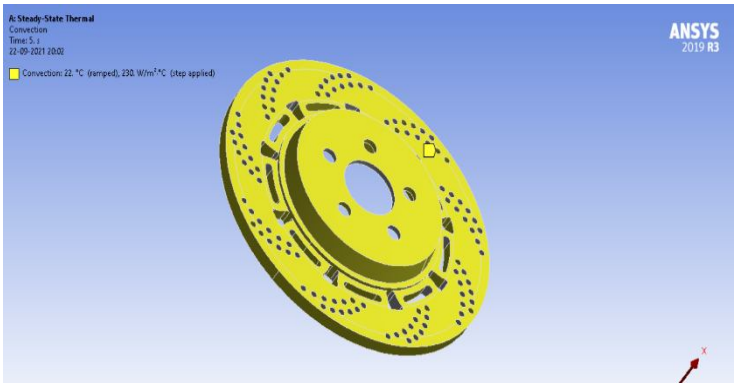

Fig.7 Convection

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Material properties of cast iron and stainless steel

Material properties	Gray cast iron	Stainless steel
Thermal conductivity (w/m k)	50	36
Specific heat, c (J/Kg c)	380	320
Thermal expansion, α (10-6 / k)	0.16	0.12
Elastic modulus, E (GPa)	110	210
Film co-efficient h (w/km2)	280	240

IV. RESULTS

A. For Gray Cast Iron

After thermal analysis of the disc brake, it is found that the maximum and the minimum temperature that the disc gains is 66.881 C and 23.363 C respectively.

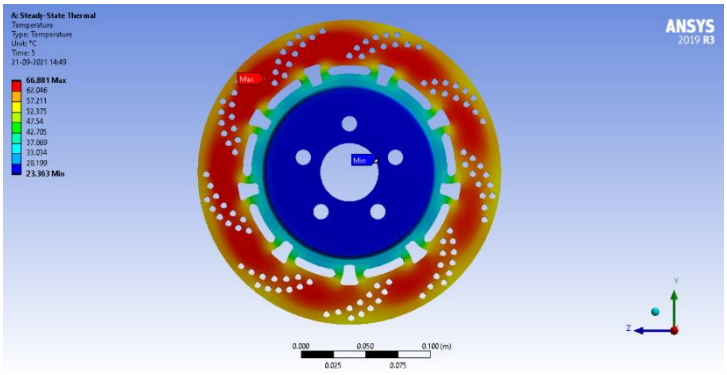

Fig.8 Thermal analysis of gray cast iron

B. For Stainless Steel

With same conditions as used for the analysis of a gray cast iron, the results for stainless steel are; the maximum temperature the disc reached is 79.153 C, while the minimum temperature is 22.047 C

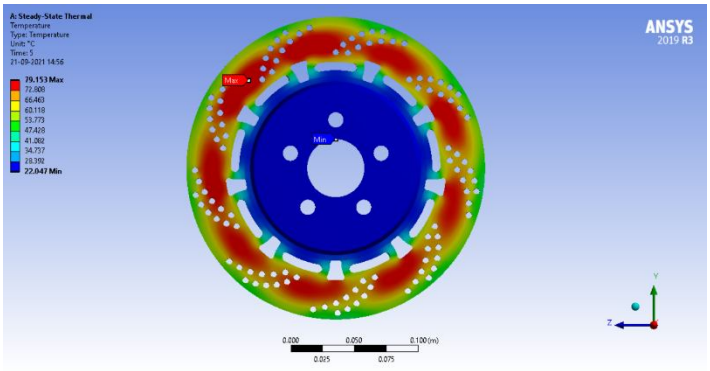

Fig.9 Thermal analysis of stainless steel

Maximum and Minimum Temperature Distribution Table

Material	Temperature (C)	
	min	max
Gray cast iron	21.363	66.881
Stainless steel	22.047	79.153

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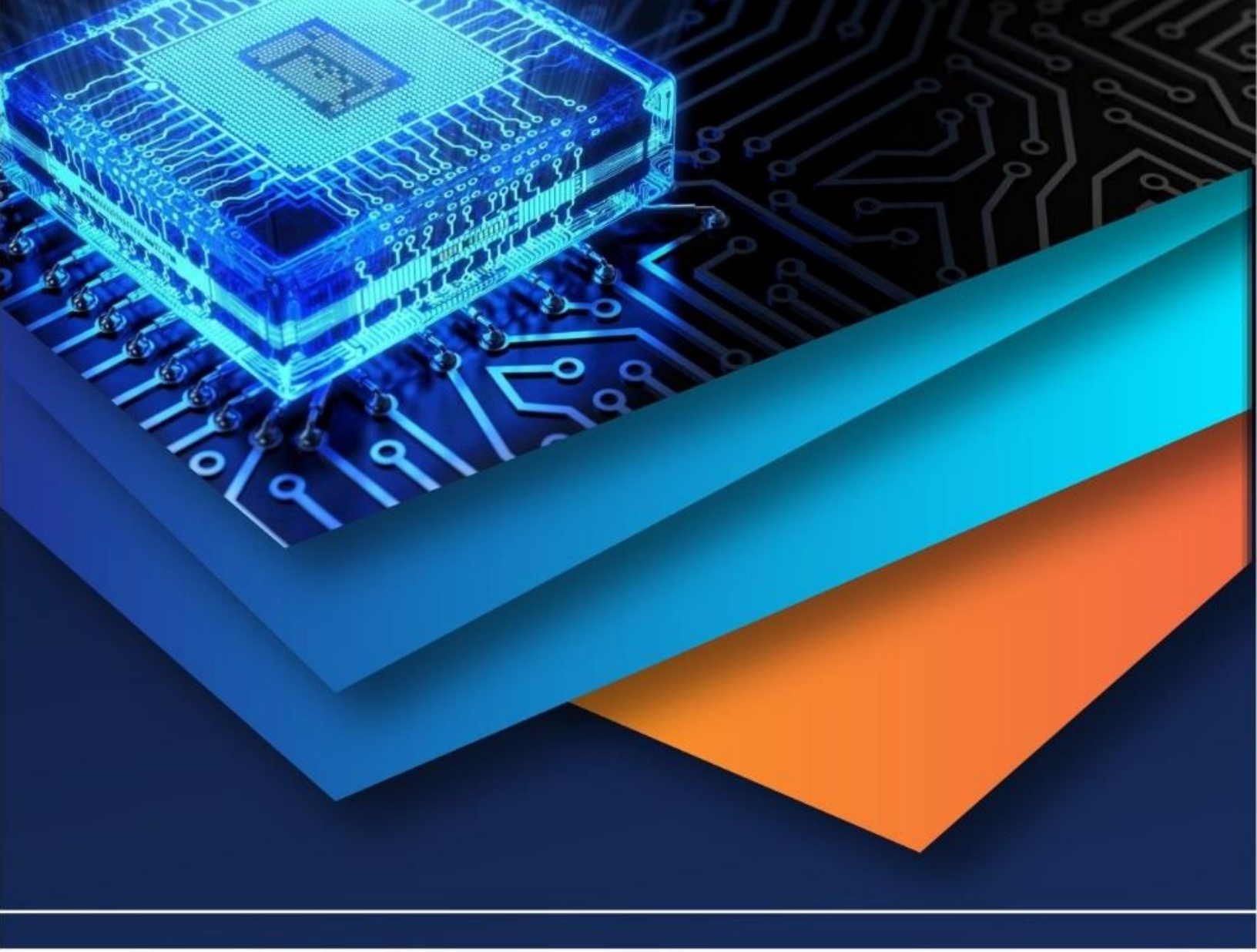

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