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Steady State Analysis and Optimization Design of Passengers Car Disc Brake

S. Udhaya Kumar[1], B. Venkata Durga Prasad[2], K. Deepak[3]
[1]Assistant Professor Department of Automobile Engineering,
Hindusthan Institute of Technology, Coimbatore, Tamil Nadu, India.
[2,3] Student Department of Automobile Engineering, Hindusthan Institute of Technology, Coimbatore, Tamil Nadu, India.

Abstract*:- The Disc Brake is a device to halt the movement of a vehicle, a brake is a mechanical device that simulates frictional safety and is attached to a moving machine part for slowing or halting the spinning of a wheel. when brakes work, they either absorb the kinetic energy of the moving component or the potential energy released by objects being lowered by lifts and other mechanisms. This project presents a design and analysis approach for a disc brake system, taking into account factors such as braking force, heat dissipation, and rotor and pad wear. The design process involves selecting appropriate materials for the cad model and determining their dimensions to ensure proper functionality. Finite element analysis (FEA) is used to simulate the performance of the brake under various operating conditions and to optimize the design for maximum efficiency and durability. To study the steady state analysis that are established in the ventilated brake disc assembly with pressure on the pads and under conditions of tightening of the disc, a 3D model of the assembly is created in CATIA V5 and imported into ANSYS R22 software. Finite Element analysis of automobile 4wheeler disc brake is performed to improvement in thermal behavior, and weight & cost" are the three main objectives of this effort. determine dissipate heat effectively to prevent the overheating, temperature and also steady state analysis is performed to analyze the thermal behavior of the dry contact between the brake disc and pads during the braking phase and optimize automotive disc brake from efficient technique from ANSYS R22 software. Hence, experimental testing using FEA analyzer technique is performed to determine both safety and performance for drivers and passengers alike.

Key Words: CATIA V5, ANSYS R22 software, Finite element analysis (FEA), Disc Brake.

1.INTRODUCTION

Disc brakes are a critical component in modern vehicles that play a vital role in the vehicle's safety and control. A disc brake typically consists of a rotor, caliper, and brake pads. When the driver applies the brake pedal, the caliper squeezes the brake pads against the rotor, generating friction that slows down the vehicle. Designing and analyzing a disc brake system requires an understanding of various factors such as the material properties of the rotor and brake pads, the geometry of the brake parts, and the optimal conditions such as temperature rise and pressure.

The analysis of the brake system involves the determination of the braking force, heat dissipation, and wear characteristics of the brake components. There are several key parameters to consider when designing and analyzing disc brakes, such as the size and thickness of the rotor, the number and size of the pistons in the caliper, the composition and quality of the brake pads, and the efficiency of the cooling system. Finite Element Analysis (FEA) is a commonly used technique to simulate the performance of the disc brake system and optimize its design. Steady-state analysis is an important tool in the design and optimization of car disc brakes, as it allows engineers to evaluate the system's performance under realistic operating conditions and identify areas for improvement.

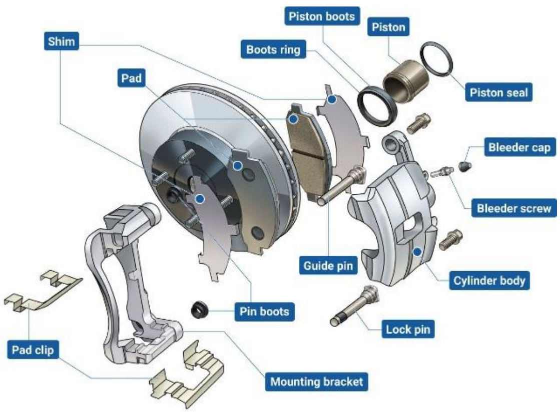

Fig 1: Disc Brake

By understanding the complex interactions between the various components of the brake system, engineers can develop more efficient designs. The ultimate goal of designing and analyzing a disc brake is to ensure its optimal performance, reliability, and safety under various driving conditions. By selecting and optimizing the brake system components, designers can ensure that the brake system can provide consistent and reliable stopping power while minimizing wear and tear on the brake components.

2.AIM & OBJECTIVES

The primary objective of designing and analyzing a disc brake system is to ensure that it can provide reliable and efficient stopping power while maintaining the safety and control of the vehicle. The following are some specific objectives of the design and analysis process:

- Determine the appropriate size and specifications for the disc brake system based on the vehicle's weight, speed, and intended use.
- Select suitable materials for the brake components, such as the rotor and brake pads, that can withstand the thermal and mechanical stresses generated during braking.
- Optimize the design of the brake components to minimize weight, reduce manufacturing costs, and improve the system's performance.
- Ensure that the brake system can effectively to prevent overheating and brake fade, which can affect the vehicle's stopping power and control.
- Determine the wear characteristics of the brake components to ensure that they have sufficient durability and longevity.
- Perform simulations and tests to evaluate the performance of the disc brake system under various driving conditions, such as emergency stops, repeated stops, and high-speed braking.
- Identify and mitigate potential failure modes of the brake system to ensure its reliability and safety.
- Overall, the design and analysis of a disc brake system aim to provide a safe, reliable, and efficient braking system that meets the vehicle's performance requirements while minimizing costs and weight.

3.LITERATURE REVIEW

- [1] Srinivas and Suresh (2016) analyzed the disc brake system's design limits, including the rotor diameter and number of vanes. They concluded that the optimum rotor diameter and thickness should be chosen to ensure that the brake system can disintegrate the heat made during braking effectively.

- [2] Singh and Dhanraj evaluated the tribological performance of different brake pad materials below varying conditions. They initiate that metallic brake pads display the highest wear resistance.

- [3] “Design and Analysis of Disc Brake Rotor Using ANSY” by Manjunath B. R. and Hemanth Kumar, this paper deliberates the design and analysis disc rotor using ANSYS software. The authors studied the stress and temperature distribution in the rotor under different effective situations and linked the results with experimental data.

- [4] "Design and Analysis of Disc Brake Assembly for an Automobile" by K. S. Rao, S. S. Patil, and S. K. Deshmukh: This paper dowries the design and analysis of a disc brake for an automobile using Finite element analysis FEA. The authors studied the stress distribution in the disc and pads and optimized the design parameters.

- [5] "A finite element study on the thermal performance of automotive disc brakes" by G. Zeghichi teal. (2014) - The academics found that the temperature spreading within the disc was non-uniform, they also found that the cooling rate of the disc reduced as the braking torque amplified.

- [6] "Experimental investigation of temperature distribution in disc brakes" by A. K. Gupta teal. - This study used infrared thermography to amount the temperature distribution inside disc brakes through steady-state braking. The researchers found that the temperature circulation was exaggerated by brake pad and the disc material.

- [7] "An experimental and numerical study of the thermal behavior of ventilated brake discs" by A. E. A. Al-Rousing - This study explored the thermal performance of discussed disc brakes under steady-state situations. The researchers found that the temperature circulation within the disc was unfair by the geometry of the airing channels, and that growing the air flow rate through the channels could central to minor disc temperatures.

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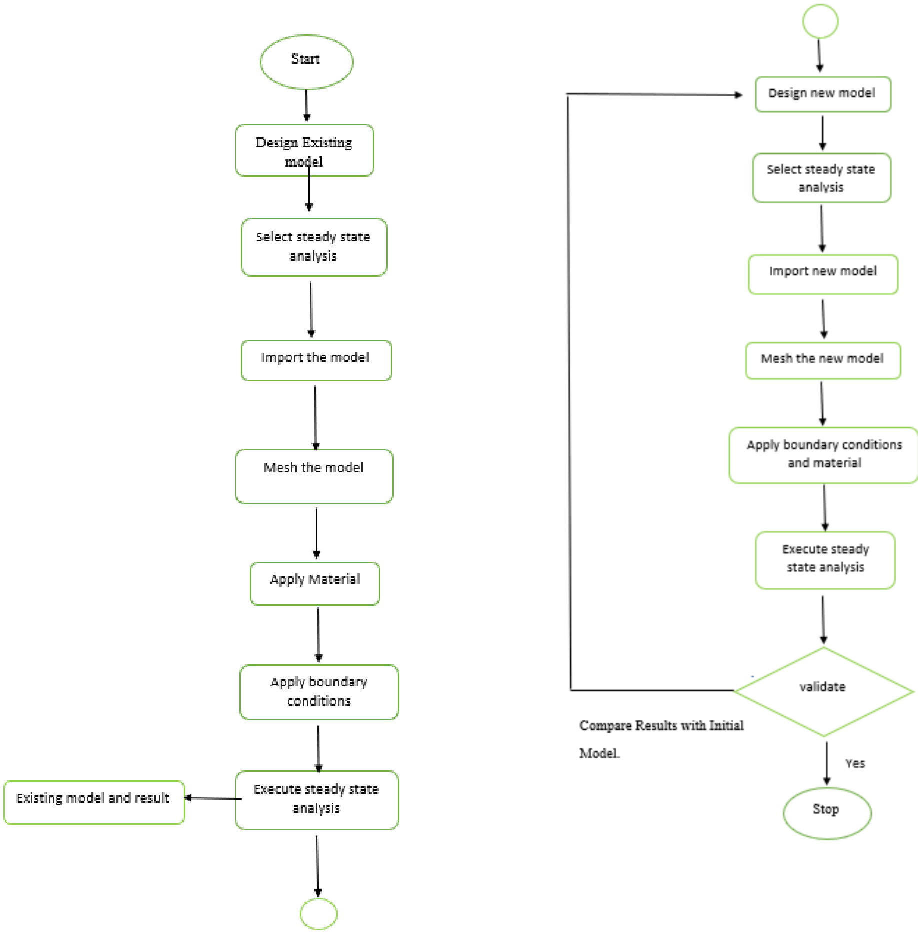
4.METHODOLOGY



4.1Existing Model

An existing model, the TATA Sumo 800 Lacer automobile disc brake, was used for the experimental investigation. The brake disc (or rotor) is the revolving component of a wheel's disc brake system against which the brake is applied. Grey iron, a kind of forged iron, is commonly used. The current model parameters are listed below.

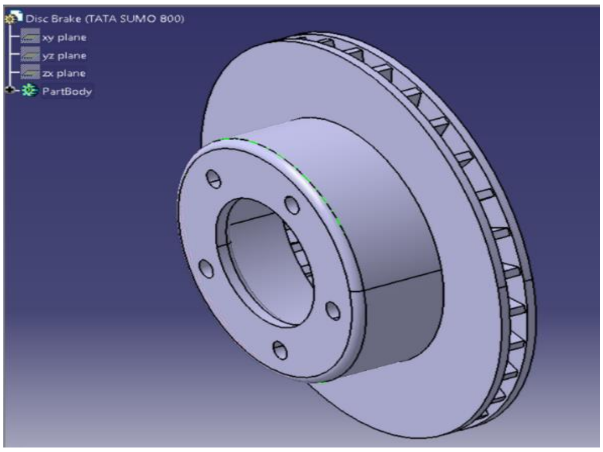


Fig.2: Existing CAD Model

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Table 1: Disc Brake Dimensions:

Parameter Name	Parameter Value
Outer Diameter of Disc	260 mm
Inner Diameter of Disc	140 mm
Hole Diameter	10 mm
Thickness of Disc	12 mm
Weight of Disc	6.2 Kg

Cad model is developed using physical dimensions of existing model and design and drafted in Catia. The exciting model was created in Catia as based on present weight of 6.2kg with the material "gray cast iron".

4.2New CAD Model

The new cad model has been developed from the existing model by minor changes in the model, the changes we have updated the shape of the vanes and created the holes to determine dissipate heat effectively to prevent the overheating, temperature and also steady state analysis is performed to analyze the thermal behavior of the dry contact between the brake disc and pads.

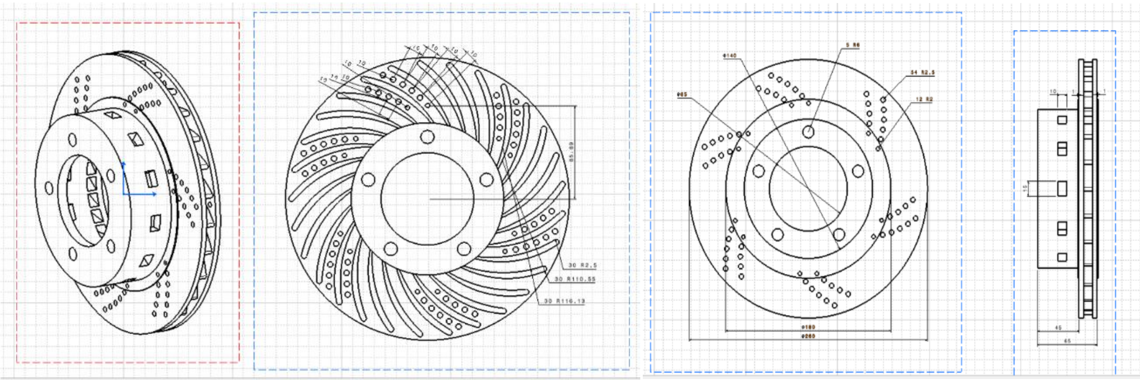

Fig.3 New Model

Table 2: Difference in Dimensions:

Parameters	New model	Excising model
Outer Diameter of Disc	260 mm	260mm
Inner Diameter of Disc	140 mm	140 mm
Hole Diameter	10mm	10 mm
Weight of Disc	6.05Kg	6.2Kg

5.STEADY STATE ANALYSIS

Steady-state thermal analysis is a type of analysis used in engineering to study the temperature distribution within a physical system that has reached a state of equilibrium, meaning that the heat input to the system is constant and the temperature distribution within the system has reached a steady state. Steady-state thermal analysis is an important tool for designing and optimizing thermal systems, such as heat exchangers, electronic devices, and engines, to ensure that they operate effectively and efficiently. It involves solving a set of mathematical equations that describe the temperature distribution within the system at the steady state.

5.1Material properties

Gray Cast iron:

Gray Cast Iron

Density	7.2e-06 kg/mm³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	1.1e+05 MPa
Poisson's Ratio	0.28
Bulk Modulus	83333 MPa
Shear Modulus	42969 MPa
Isotropic Secant Coefficient of Thermal Expansion	1.1e-05 1/°C
Compressive Ultimate Strength	820 MPa
Compressive Yield Strength	0 MPa
Tensile Ultimate Strength	240 MPa
Tensile Yield Strength	0 MPa

Fig 4: Gray Cast Iron

Titanium Alloy:

Titanium Alloy

Density	4.62e-06 kg/mm³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	96000 MPa
Poisson's Ratio	0.36
Bulk Modulus	1.1429e+05 MPa
Shear Modulus	35294 MPa
Isotropic Secant Coefficient of Thermal Expansion	9.4e-06 1/°C
Compressive Ultimate Strength	0 MPa
Compressive Yield Strength	930 MPa
Tensile Ultimate Strength	1070 MPa
Tensile Yield Strength	930 MPa

Fig 5: Titanium Alloy

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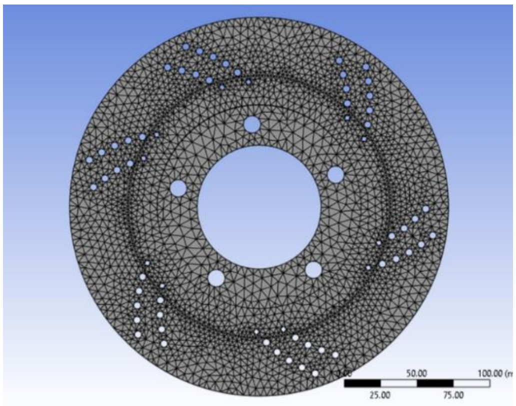
5.2 Mesh for components

We used triangular mesh in fine mesh with a mesh size of 3mm to mesh the component. Tetrahedral three-dimensional components with nodes are utilized for meshing the complete and vented discs. The meshing in the contact zone was improved in this simulation. This is noteworthy since the temperature in this zone changes greatly. Thermus mechanical gradients are really extremely high in this severely deformed zone



Statistics	
Nodes	125047
Elements	70191
Show Detailed St...	No

Fig 6: Meshed Component

5.3 Boundary Conditions

1.Temperature:

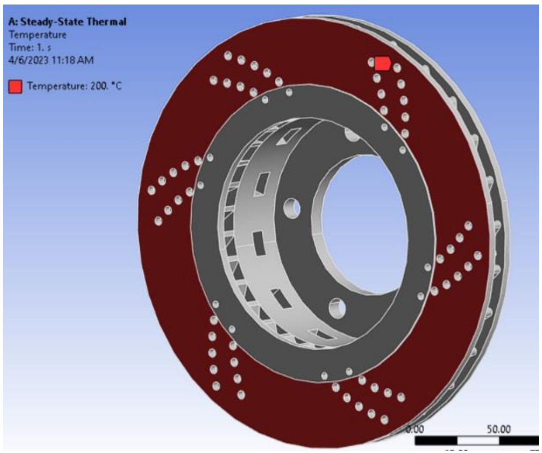


Fig 7: Temperature

2. Convention:

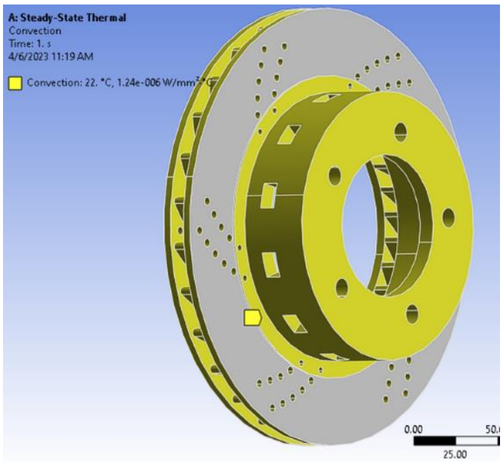


Fig 8: Convention

6.RESULT

An enduring steady state analysis ascertains the impacts of unfaltering thermal loads on a framework or part. Engineer/investigators frequently perform an enduring state investigation before doing a transient thermal analysis, to help create starting conditions.

6.1 TEMPERATURE

Existing Model

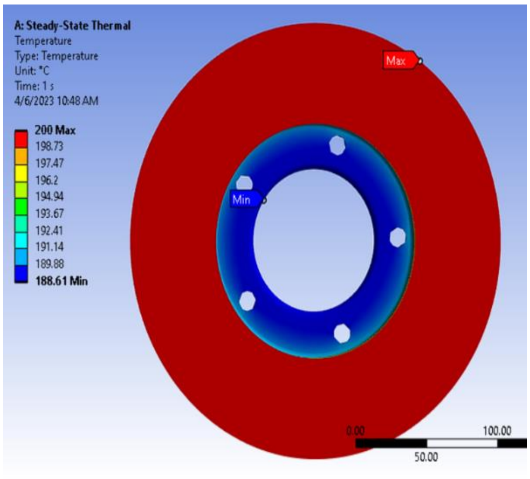


Fig. 9: Gray Cast Iron

New Model

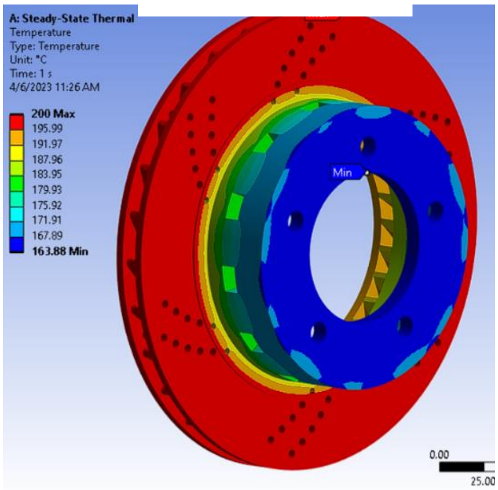


Fig. 10: Gray Cast Iron

New Model

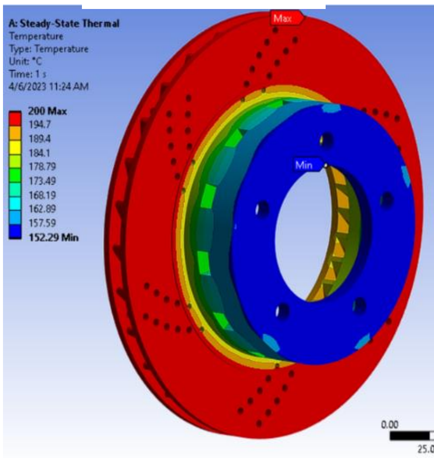


Fig.11: Titanium alloy

6.2 HEAT FLUX

Existing Model

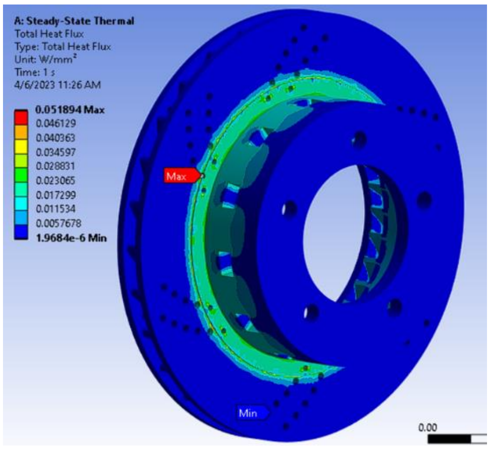


Fig. 12: Gray Cast Iron

New Model

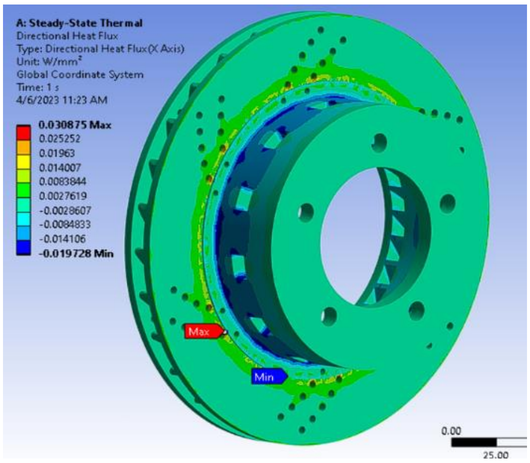


Fig. 13: Gray Cast Iron

New Model

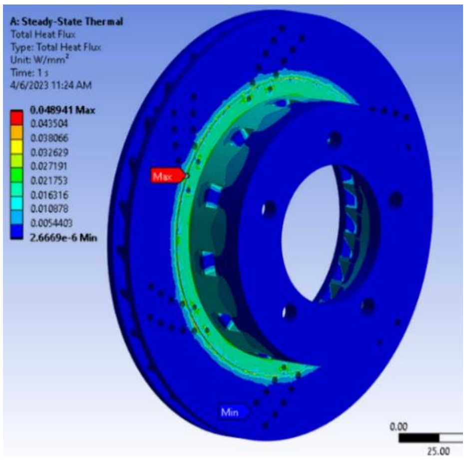


Fig.14: Titanium alloy

6.3 DIRETIONAL HEAT FLUX

Existing Model

New Model

New Model

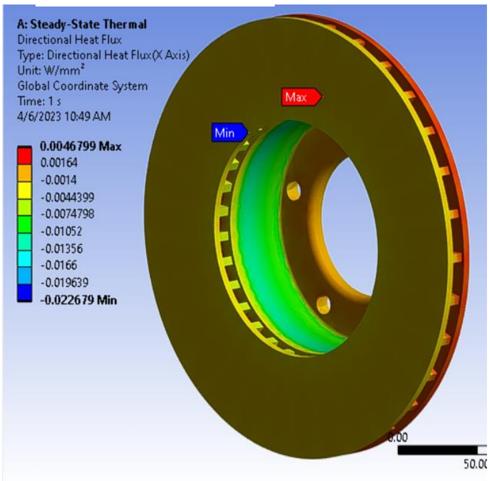


Fig. 15: Gray Cast Iron

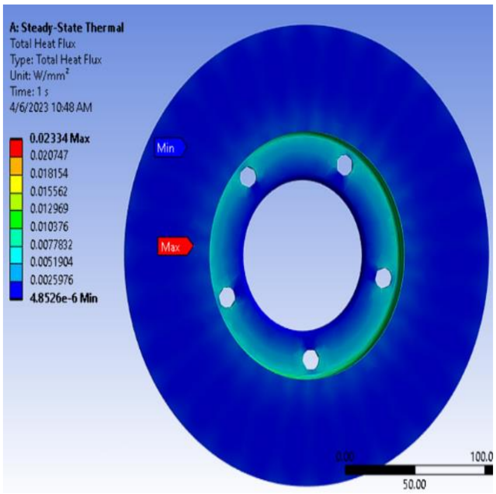


Fig. 16: Gray Cast Iron

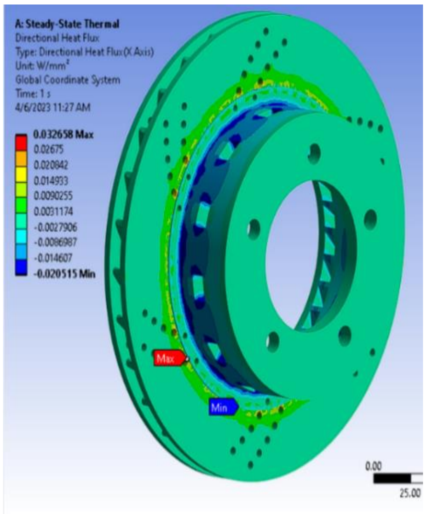


Fig.17: Titanium alloy

Table 3: Comparison of Results

Result	Cast iron (Existing model)		Cast iron (New model)		tritium Alloy (New Model)	
	min	max	min	max	min	max
Temperature (˚c)	188.61	200	182.66	200	163.88	200
Heat Flux (W/mm²)	4.85E-06	0.02334	4.17E-06	0.056441	1.97E-06	0.051894
Directional Heat Flux (W/mm²)	-0.022679	0.0046799	-0.022732	0.035402	-0.020515	0.032658
weight of the component	6.2Kg		6.05Kg		4.5Kg	

CONCLUSION

A clear comparison is done between the outcomes from the tables 3 on the basis of each field, the new cad model disc brake is originated to deform in a relatively advanced rate on applying the same load. This paper clarifies about the design of a straight & vented brake discs with Titanium alloy is efficient than the gray cast iron in Temperature, Heat flux and Directional Heat Flux. It also comprises the meshed component with applying the temperatures with two different materials. In conclusion, both the disc brake has been analyzed in Ansys R21 for the Steady Static Thermal analysis. In these outcomes, we get that, by changing the straight vents to curved vents, making holes and slots in the brake disc. This design of the brake components has minimized weight, reduce manufacturing costs, and improve the system's performance The Temperature & mass of the brakes disc has been compact. And also curved vented brake disc with Titanium alloy is generated a high thermal flux and Directional Heat Flux than an Existing Disc brake.

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