

DESIGN AND THERMAL ANALYSIS ON DISC BRAKE ROTOR USING SOLIDWORKS

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in partial fulfillment of the requirements for the award of the degree of
BACHELOR OF TECHNOLOGY

In
MECHANICAL ENGINEERING

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ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES

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CERTIFICATE

This is to certify that the Project Report entitled “**DESIGN AND THERMAL ANALYSIS ON DISC BRAKE ROTOR USING SOLID WORKS**” being submitted by SINGAMPALLI LOKESH (317126520051), PITCHIKA SRI LALITHA (317126520040), SATTARU VENKATA BALAJI NAIDU (317126520047), MALLA NIKHIL CHAKRAVARTHI (317126520032), BOTTA BHASKARA ADITYA SAI YESWANATH (317126520009) in partial fulfillments for the award of degree of **BACHELOR OF TECHNOLOGY** in **MECHANICAL ENGINEERING**. It is the work of bona-fide, carried out under the guidance and supervision of **MRS.P.RAMYA**, Assistant Professor, Department Of Mechanical Engineering, ANITS during the academic year of 2017-2021.

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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.

When a vehicle is in motion, it is said to have kinetic energy. Brakes are designed to stop the vehicle by absorbing the kinetic energy of the vehicle and dissipating it in the form of heat. The kinetic energy of a vehicle is given by the following equation: where 'm' is the mass of the vehicle and 'v' is the velocity of the vehicle. If the mass of the vehicle is large, or the velocity is large, this can amount to a large amount of energy dissipated in the form of heat. The braking mechanism must be able to withstand both the temperatures generated by this heating as well as the forces incurred during breaking. we will investigate the design of the braking rotor. The vehicle will be moving at full speed and will be braked to a complete stop. a thermal analysis will be run to calculate the temperature distribution in the brake rotor during braking.

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CHAPTER 1

INTRODUCTION

1.1 Brake:

A brake is a mechanical device that inhibits motion by absorbing energy from a moving system. It is used for slowing or stopping a moving vehicle, wheel, axle, or to prevent its motion, most often accomplished by means of friction.

The conversion of kinetic energy into heat energy is a function of frictional force generated by the frictional contact between brake shoes and moving drum or disc of a braking system.

1.2 Importance of brakes:

In an automobile braking system is important for following reasons-

- To stop the moving vehicle.
- To de accelerate the moving vehicle.
- For stable parking of a vehicle either on a flat surface or on a slope.
- As a precaution for accidents.
- To prevent the vehicle from any damage due to road conditions.

1.3 Types of brakes:

Brakes are perhaps the most important safety feature of any vehicle. Knowing the different types of brakes, both between and within vehicles, can help you feel better informed when caring for and repairing your brakes.

There are two kinds of service brakes, or the brakes that stop your vehicle while driving: disc and drum brakes. Additionally, almost all vehicles come with emergency brakes and anti-lock brakes.

1.3.1 Drum brake:

Drum brakes consist of a brake drum attached to the inside of the wheel. When the brake pedal contracts, hydraulic pressure presses two brake shoes against the brake drum. This creates friction and causes the vehicle to slow and stop.



Fig 1.1 DRUM BRAKE

1.3.2 Emergency brake:

Emergency brakes, also known as parking brakes, are a secondary braking system that work independent of the service brakes. While there are many different kinds of emergency brakes (a stick lever between the driver and passenger, a third pedal, a push button or handle near the steering column, etc.), almost all emergency brakes powered by cables which mechanically apply pressure to the wheels. They are generally used to keep a vehicle stationary while parked, but can also be used in emergency situations if the stationary brakes fail.



Fig 1.2 EMERGENCY BRAKE

1.3.3 Anti-lock brake:

Anti-lock braking systems (ABS) are found on most newer vehicles. If the stationary brakes are applied suddenly, ABS prevent the wheels from locking up in order to keep the tires from skidding. This feature is especially useful when driving on wet and slippery roads.



Fig 1.3 ANTI-LOCK BRAKE

1.3.4 Disc brake:

Disc brakes consist of a brake rotor which is attached directly to the wheel. Hydraulic pressure from the master cylinder causes a caliper (which holds the brake pads just outside the rotor) to squeeze the brake pads on either side of the rotor. The friction between the pads and the rotor causes the vehicle to slow and stop.



Fig 1.4 DISC BRAKE

1.4 Components of Disc brake:

A disc brake consists of four different parts. These components work together to form a functional and complete brake system.

1.4.1 Brake discs:

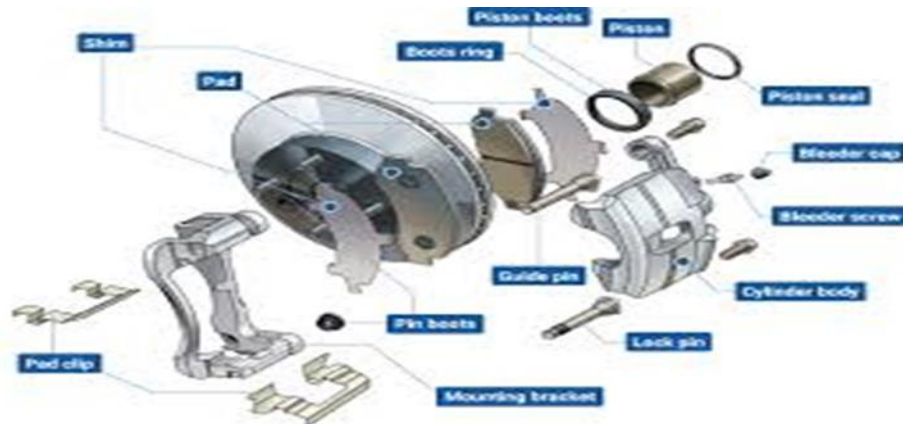


Fig 1.5 BRAKE DISC

What they are: Sometimes called brake rotors, sometimes called discs, this brake part is one of the main components of disc brakes. When brake pads press against the disc/rotor on each side, it causes the system to slow down or stop.

How long they last: As with all brake parts, it can vary, but brake rotors/discs tend to last anywhere from 30,000 to 70,000 miles. You can also extend their life with brake resurfacing. They should be inspected every 12,000 miles, however.

When to replace: The surface is where this brake part wears down. Over time, grooves or ridges can develop where the brake pads press down on them. If the brake pads can't maintain an even contact surface, you may experience grinding, meaning it's time to resurface or replace the rotors or discs. It's recommended to replace brake rotors/discs in pairs.

1.4.2 Brake pads:

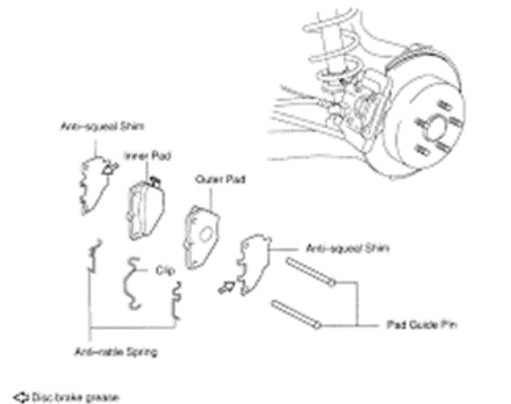


Fig 1.6 BRAKE PADS

What they are: Also a component in disc brakes, brake pads press on the brake rotors/discs to slow them down. They sit in the brake calipers and are activated by brake pistons.

How long they last: How long a brake pad lasts depends on its quality. Harder pads last longer than soft pads, but overall, they'll last until the padding is worn down to the metal "shoe" part of the brake pad. Pads last 40,000 miles or so on average but can vary from less than 25,000 miles to more than 65,000 miles.

When to replace: Squealing is a good indicator that there is an issue with your brake pads. Many cars have a brake warning sensor that lets you know when it's time to get your brake pads checked immediately.

1.4.3 Brake calipers:

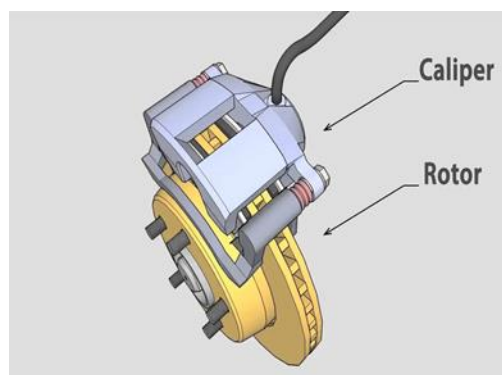


Fig 1.7 BRAKE CALIPERS

What they are: Calipers can be floating or fixed, and they house the brake pads, brake pistons and brake fluid. Think of them like a clamp. They're crucial for creating friction that slows down your brake rotors or discs.

How long they last: Caliper lifespan depends a lot on how actively you use your car. If it sits for a while, the caliper may break down, stick or collect debris. It's also possible you may need to fix a seized brake caliper. But in general, calipers can last a long time with good maintenance.

When to replace: The main issue that pops up with brake calipers is with their seals, which can break down due to the heat in the brake system. But there can also be grinding due to the disc and caliper rubbing together. Get your calipers checked with the rest of your brake system every 12,000 miles.

1.4.4 Brake piston:



Fig 1.8 BRAKE PISTON

What they are: Pistons press against brake pads to create friction on the brake rotors/discs. They're activated by brake fluid and sit within the brake calipers. There are usually one or two pistons per brake, but there can be more than one pair.

How long they last: Brake pistons can erode or stick, which causes issues with the brake pads applying properly to the discs or rotors when they're activated. Their lifespan is very similar to brake calipers but can also vary.

When to replace: If the brake is sticking or your car is leaking brake fluid, it could be a sign that brake pistons need to be replaced. More often than not, it's another brake component issue, which is why a brake inspection is so important.

1.5 Working principle:

- When brake pedal is pressed, the high-pressure fluid from the master cylinder pushes the piston outward.
- The piston pushes the brake pad against the rotating disc.
- As the inner brake pad touches rotor, the fluid pressure exerts further force and the caliper moves inward and pulls the outward brake pad towards the rotating disc and it touches the disc.

- Now both the brake pads are pushing the rotating disc, a large amount of friction is generated in between the pads and rotating disc and slows down the vehicle and finally let it stop.
- When brake pad is released, the piston moves inward, the brake pad away from the rotating disc. And the vehicle again starts to move.

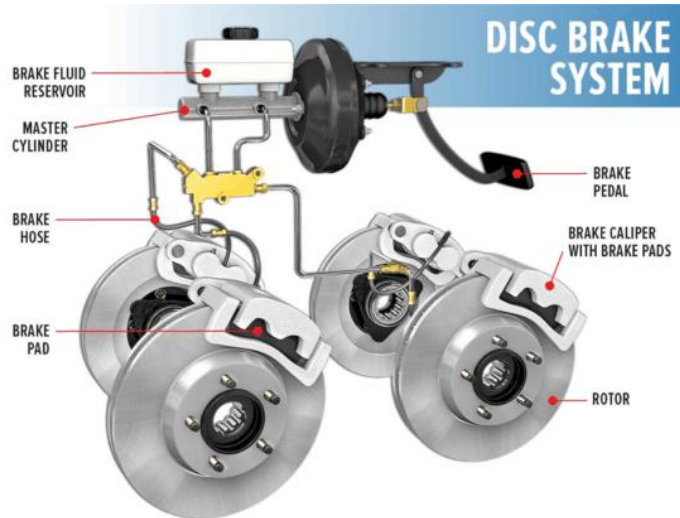


Fig 1.9 DISC BRAKE SYSTEM

Disc Brake Operation (floating caliper single piston)

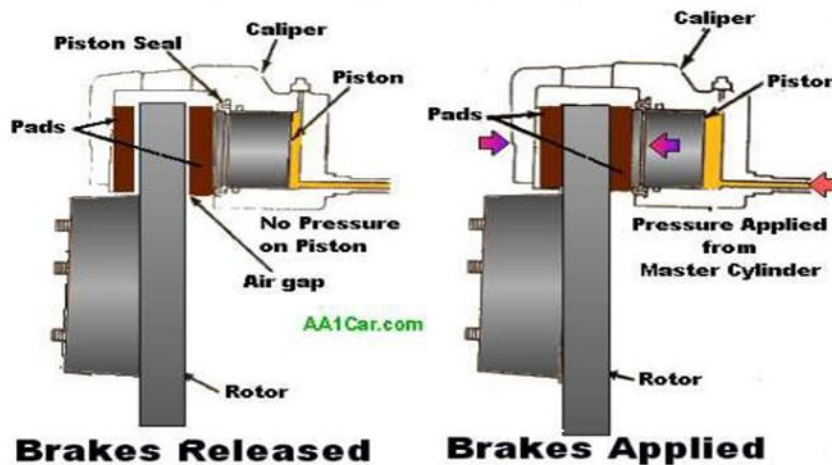


Fig 1.10 WORKING OF DISC BRAKE

1.6 Types of Rotor:

When it comes time to replace rotors, not all rotors are made the same. In fact, there are four different types to choose from depending on the vehicle type, load carried etc, so before replacing vehicle's rotors, choosing the right one for needs is important. The four different rotor types are:

1.6.1 Blank or smooth rotor:

Blank or smooth rotor is also called as “Solid Surface Brake Rotors”. They have a smooth or plain surface, with no holes or markings in the metal. They provide the most surface area to create friction with the pads. They are strong and durable. Blank rotors are a great choice for new passenger vehicles.

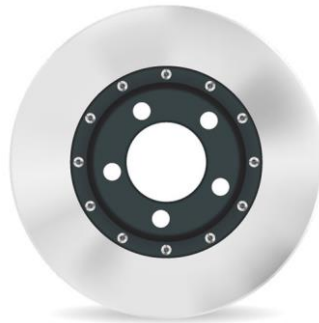


Fig 1.11 BLANK OR SMOOTH ROTOR

1.6.2 Drilled rotor:

Drilled rotors have holes drilled throughout the surface. These holes allow water, dust, and heat to easily dissipate off the surface of the rotor. Drilled rotors are used by the drivers that live in wetter climates as they'll help increase stopping power in wet, rainy conditions.



Fig 1.12 DRILLED ROTOR

1.6.3 Slotted rotor:

Slotted rotors feature slots around the exterior surface of the rotor. They're a great choice for heavy-duty trucks and SUVs, especially those that need improved stopping power when towing or hauling. The slots are designed to draw more air in between the pad and rotor surface, which improves cooling and heat dispersion. They're also designed to help remove excess brake debris and pad glaze that can occur at higher temperatures.



Fig 1.13 SLOTTED ROTOR

1.6.4 Drilled and slotted rotor:

Drilled and slotted rotors are primarily designed for performance vehicles, like sports cars, that need enhanced cooling and heat dispersion. This type of rotor was designed to improve braking at high speeds during racing or track days.



Fig 1.14 DRILLED AND SLOTTED ROTOR

2.LITERATURE SURVEY

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)

Comparision of 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.

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. Modelling is done in Catia and Analysis is done in ANSYS.



Fig 2.1 Blank rotor



Fig 2.2 Drilled rotor

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 300°F. 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 300°F. The displacement increased as compared with the previous case. This is due to the thermal expansion of the individual parts in the assembly. 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

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 index for 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.

6. Gao and Lin

They Presented Transient temperature field analysis of a brake in a non-axisymmetric three-dimensional model. The disc brake pads used in an automobile is divided into two parts: the disc, geometrically axisymmetric; and the pad, of which the geometry is three-dimensional. Using a two-dimensional model for thermal analysis implies that the contact conditions and frictional heat flux transfer are independent of y . this may lead to false thermal elastic distortions and unrealistic contact conditions.

An analytical model is presented in this paper for the determination of the contact temperature distribution on the working surface of a brake. To consider the effects of the moving heat source with relative sliding speed variation, a transient finite element technique is used to characterize the temperature fields of the solid rotor with appropriate thermal boundary conditions. Numerical results shows that the operating characteristics

of the brake exert an essentially influence on the surface temperature distribution and the maximal contact temperature.

7. Voller, et al

In 2003 performed an analysis of automotive disc brake cooling characteristics. The aim of this investigation was to study automotive disc brake cooling characteristics experimentally using a specially developed spin rig and Singh and Shergill 85 numerically using finite element (FE) and computational fluid dynamics (CFD) methods. All the three modes of heat transfer (conduction, convection, radiation) have been analyzed along with the design features of the brake assembly and their interfaces. The influences of the brake cooling parameters on the disc brake temperature had been investigated by FE modelling of a long drag brake application. The thermal power dissipated during the drag brake application has been analyzed to reveal the contribution of each mode of heat transfer.

8. Choi and Lee

In 2004 they presented a paper on Finite element analysis of transient thermoelastic behaviors in disc brakes. A transient analysis for thermoelastic contact problem of disc brakes with frictional heat generation is performed using the finite element method. To analyze the thermoelastic phenomenon occurring in disc brakes is obtained in the repeated brake condition. The computational results are presented for the distribution of pressure and temperature on each friction surface between the contacting bodies.`

3. Materials used

3.1 Grey Cast Iron:

Grey cast iron (GCI) is a popular automotive brake disc material by virtue of its high melting point as well as excellent heat storage and damping capability. GCI is also attractive because of its good castability and machinability, combined with its cost-effectiveness. Although several lightweight alloys have been explored as alternatives in an attempt to achieve weight reduction, their widespread use has been limited by low melting point and high inherent costs. Therefore, GCI is still the preferred material for brake discs due to its robust performance.

However, poor corrosion resistance and excessive wear of brake disc material during service continue to be areas of concern, with the latter leading to brake emissions in the form of dust and particulate matter that have adverse effects on human health. With the exhaust emission norms becoming increasingly stringent, it is important to address the problem of brake disc wear without compromising the braking performance of the material. Surface treatment of GCI brake discs in the form of a suitable coating represents a promising solution to this problem. This paper reviews the different coating technologies and materials that have been traditionally used and examines the prospects of some emergent thermal spray technologies, along with the industrial implications of adopting them for brake disc applications.

Table 3.1 Properties of Grey cast iron

Property	value	Units(SI)
Shear Modulus	50000	N/mm ²
Mass density	7200	Kg/m ³
Tensile strength	151.658	N/mm ²
Compressive strength	572.165	N/mm ²
Yield strength		N/mm ²
Thermal expansion coefficient	1.2e ^{-0.5}	/K
Thermal conductivity	45	W/(M.K)
Specific heat	510	J/(kg.K)

3.2 Copper:

Copper makes for a smooth braking experience, transfers heat efficiently and helps brakes effectiveness in cold weather. Copper also has properties that help prevent brakes from squeaking and shuddering when used. Currently, copper's unique qualities will make it difficult to replicate with other materials.

The primary reason for the use of copper is to increase the thermal conductivity and eliminate thermal fade of brake pads.

Table 3.2 Properties of Copper

Property	value	Units(SI)
Poisson's ratio	0.37	N/A
Shear Modulus	40000	N/mm ²
Mass density	8900	Kg/m ³
Tensile strength	394.38	N/mm ²
Compressive strength		N/mm ²
Yield strength	258.646	N/mm ²
Thermal expansion coefficient	1.2e ⁻⁵	/K
Thermal conductivity	390	W/(M.K)
Specific heat	390	J/(kg.K)

3.3 Brass:

The addition of brass particles in the formulation of the brake pad material affects the thermal properties in a beneficial way. The organic matrix composites having more brass in their formulations can dissipate more heat generated by friction leading a higher fade resistance.

Table 3.3 Properties of Brass

Property	value	Units(SI)
Poisson's ratio	0.33	N/A
Shear Modulus	37000	N/mm ²
Mass density	8500	Kg/m ³
Tensile strength	478.413	N/mm ²
Compressive strength		N/mm ²
Yield strength	239.689	N/mm ²
Thermal expansion coefficient	1.8e ⁻⁵	/K
Thermal conductivity	110	W/(M.K)
Specific heat	390	J/(kg.K)

3.4 Ductile Iron:

Table 3.4 Properties of Ductile Iron

Property	value	Units(SI)
Poisson's ratio	0.31	N/A
Shear Modulus	77000	N/mm ²
Mass density	7100	Kg/m ³
Tensile strength	861.695	N/mm ²
Compressive strength		N/mm ²
Yield strength	551.485	N/mm ²
Thermal expansion coefficient	1.8e ^{-0.5}	/K
Thermal conductivity	75	W/(M.K)
Specific heat	450	J/(kg.K)

3.5 Silicon:

carbon/silicon-carbide or carbon/carbon–silicon-carbide composites that are commonly produced from carbon/carbon composites impregnated with liquid silicon by the liquid-silicon infiltration (LSI) process. In this work, a new ceramic matrix composite friction material for brake discs was developed that combines a high fracture toughness with good oxidation and abrasion resistance, good thermal conductivity, and the appropriate friction characteristics. For the production of such materials, the “dual-matrix” approach combined with reactive sintering was used. The materials have suitable mechanical properties and the braking discs have appropriate coefficient of friction and very low wear rate.

Table 3.5 Properties of Silicon

Property	value	Units(SI)
Poisson's ratio	0.28	N/A
Shear Modulus	49000	N/mm ²
Mass density	2300	Kg/m ³
Tensile strength		N/mm ²
Compressive strength		N/mm ²
Yield strength	120	N/mm ²
Thermal expansion coefficient		/K
Thermal conductivity	124	W/(M.K)
Specific heat		J/(kg.K)

3.6 Magnesium alloy:

The invention relates to a magnesium alloy brake disc, and in particular relates to a carbon fiber reinforced magnesium base composite material for the brake disc and a preparation method of the composite material. The carbon fiber reinforced magnesium base composite material for the brake disc is prepared by taking a magnesium-aluminum-zinc-manganese series magnesium base alloy as a matrix and micro-nano scale carbon fibers as a reinforcing phase of the magnesium alloy matrix, and carrying out a melt synthesis-compression molding method. Compared with the prior art, through carbon fiber reinforcement, the fatigue resistance and wear resistance of the magnesium base alloy material are improved, and the material is high in friction factor, good in braking effect and long in service life and can be applied to brake discs of various motor vehicles.

Table 3.6 Properties of Magnesium alloy

Property	value	Units(SI)
Poisson's ratio	0.35	N/A
Shear Modulus	17000	N/mm ²
Mass density	17300	Kg/m ³
Tensile strength		N/mm ²
Compressive strength		N/mm ²
Yield strength		N/mm ²
Thermal expansion coefficient		/K
Thermal conductivity	160	W/(M.K)
Specific heat	1000	J/(kg.K)

3.7 Steel:

Steel is having good corrosion resistance and can be hardened to get good wear resistance which is required for brakes disc.

Table 3.7 Properties of Steel

Property	value	Units(SI)
Poisson's ratio	0.28	N/A
Shear Modulus	79000	N/mm ²
Mass density	7700	Kg/m ³
Tensile strength	723.8256	N/mm ²
Compressive strength		N/mm ²
Yield strength	620.422	N/mm ²
Thermal expansion coefficient	1.3e ^{o.5}	/K
Thermal conductivity	50	W/(M.K)
Specific heat	460	J/(kg.K)

4. MODELLING OF DISC BRAKE ROTOR

4.1 Introduction to SolidWorks:

SOLIDWORKS is design automation software. In Solid Works, you sketch ideas and experiment with different designs to create 3D models. Solid Works is used by students, designers, engineers, and other professionals to produce simple and complex parts, assemblies, and drawings.

SOLIDWORKS works the way engineers design and think and that is why it has become successful so quickly. Engineers and drafters say that it is easy to learn and gives them a model that they have complete confidence in manufacturing and know that it will work, just by using the tools provided with this one piece of software. Solid works is powerful.



Fig 4.1 Solid works interface

- At the top left corner, select PART from the dialog box shown and select OK. The first part of the drawing can be made. Basically, solid works model is made up of PART, ASSEMBLY and DRAWING modules.
- A plane has to be selected to start the sketch. According to the requirement of the drawing, select the plane (as shown in the figure 3.2) in which the part must be drawn.
- The required sketch of the part is drawn. The dimensions are given using smart dimensions tab.
- After constructing all the parts of the component, assemble the parts to obtain the component. Further obtain the drawing of the component.

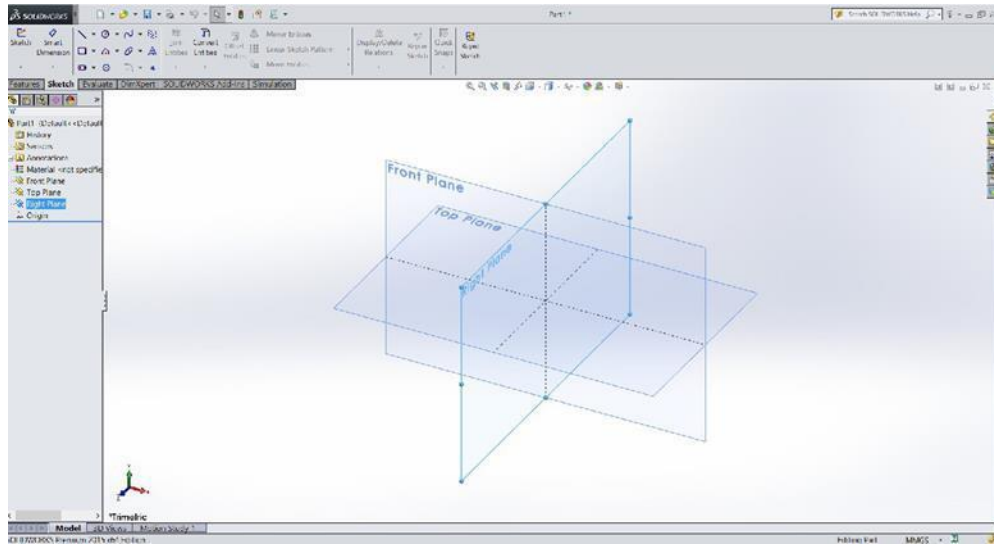


Fig 4.2 Plane selection

4.1.1 Terminology:

These terms appear throughout the Solid Works software and documentation as shown in the figure 3.3.

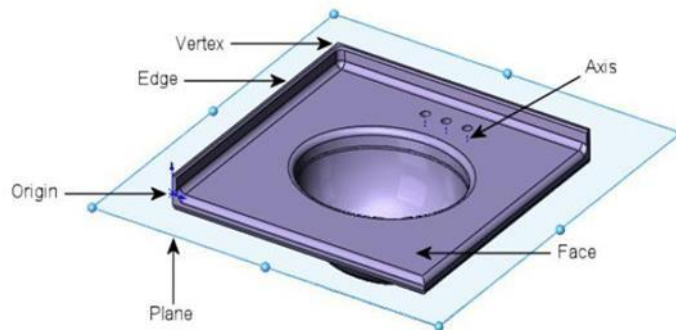


Fig 4.3 Model terminology

- Origin: Appears as two blue arrows and represents the (0, 0, 0) coordinate of the model. When a sketch is active, a sketch origin appears in red and represents the (0, 0, 0) coordinate of the sketch. You can add dimensions and relations to a model origin, but not to a sketch origin
- Plane: Flat construction geometry. You can use planes for adding a 2D sketch, section view of a model, or a neutral plane in a draft feature, for example.

- **Axis:** Straight line used to create model geometry, features, or patterns. You can create an axis in different ways, including intersecting two planes. The Solid Works application
- **Face:** Boundaries that help define the shape of a model or a surface. A face is a Selectable area (planar or non-planar) of a model or surface. For example, a rectangular solid has six faces.
- **Edge:** Location where two or more faces intersect and are joined together. You can select edges for sketching and dimensioning, for example.
- **Vertex:** Point at which two or more lines or edges intersect. You can select vertices sketching and dimensioning, for example.

4.2 Modelling of Disc brake rotor:

4.2.1 Disc brake rotor specifications:

A typical Disc brake rotor is chosen for study. The disc brake rotor dimensions are shown in below table.

Table 4.1 Dimensions of Disc brake rotor

S.No.	Parameter	Value
1	Outer diameter of the rotor disc	221mm
2	Inner diameter of rotor disc	133mm
3	Hole diameter	60mm
4	Thickness of rotor disc	10mm
5	Caliper piston diameter	44mm
6	Mass of disc	2.9kg

4.2.2 Procedure for design:

1. Go to features, select part diagram click on OK.

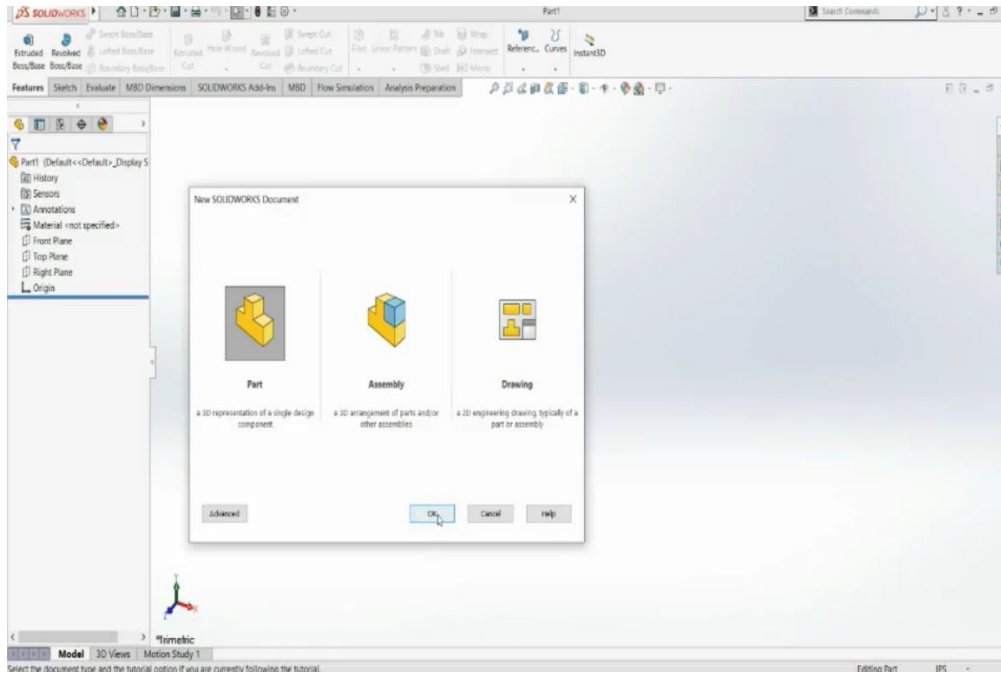


Fig 4.4 selection of solidwork document

2. Change the dimensions to MMGS. Go to sketch and select front plane.

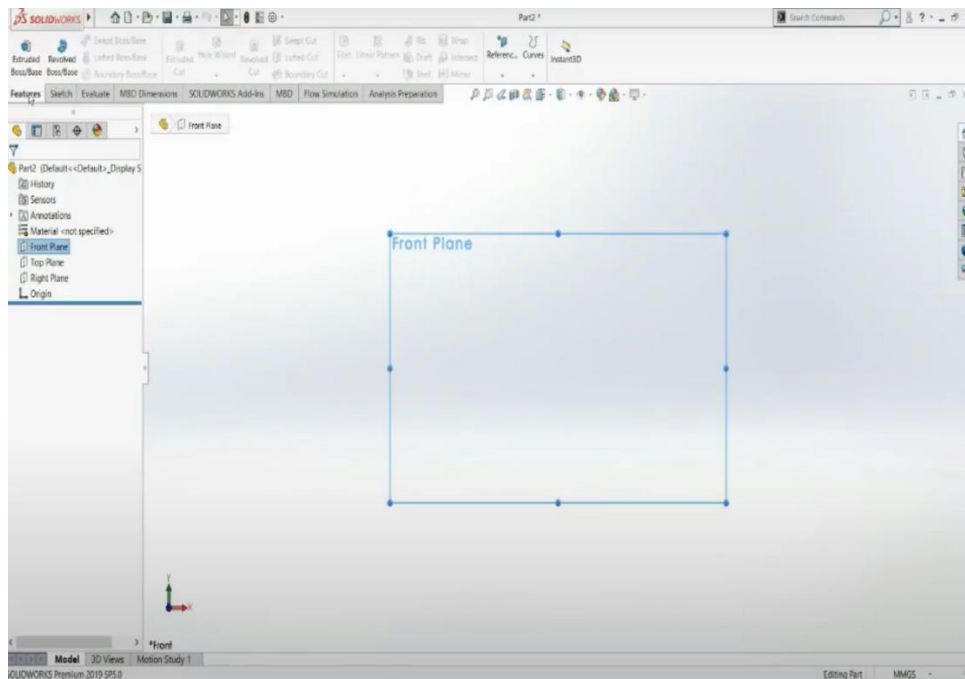


Fig 4.5 selection of plane

3. Using circle and smart dimensions commands draw a circle with 221mm diameter, extrude the circle to 10mm using extrude boss command.

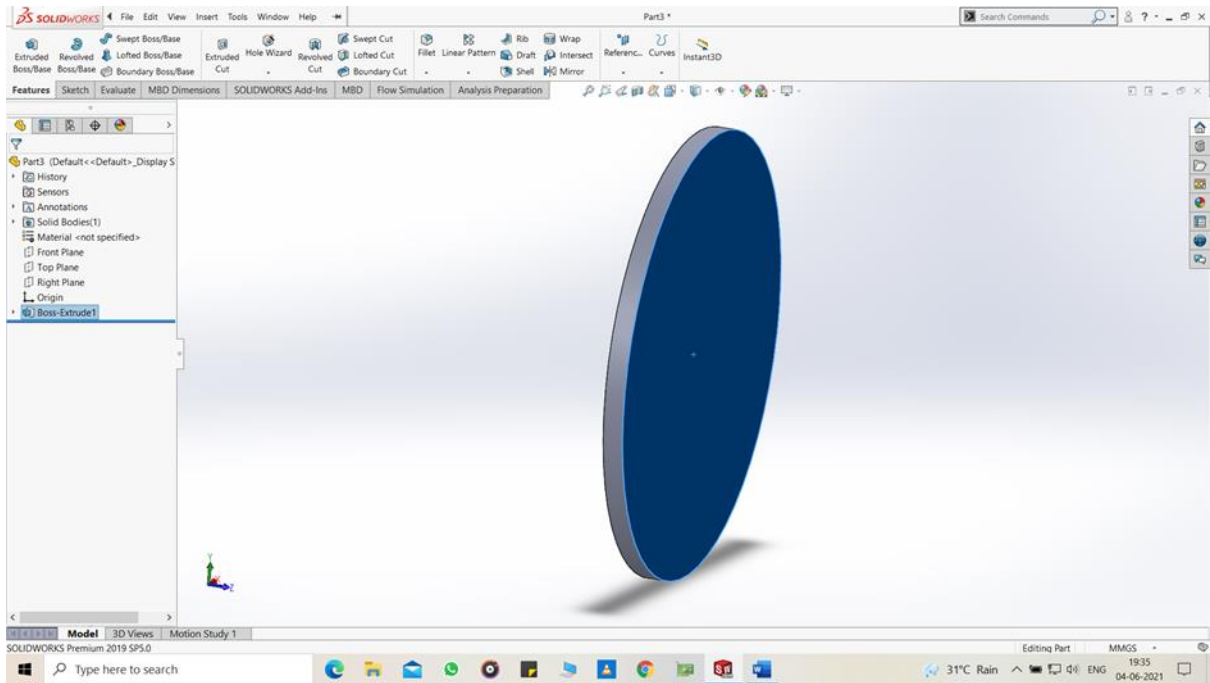


Fig 4.6 Boss extrude

4. Now draw another circle with diameter 133mm, select merge result and extrude it to 35mm.

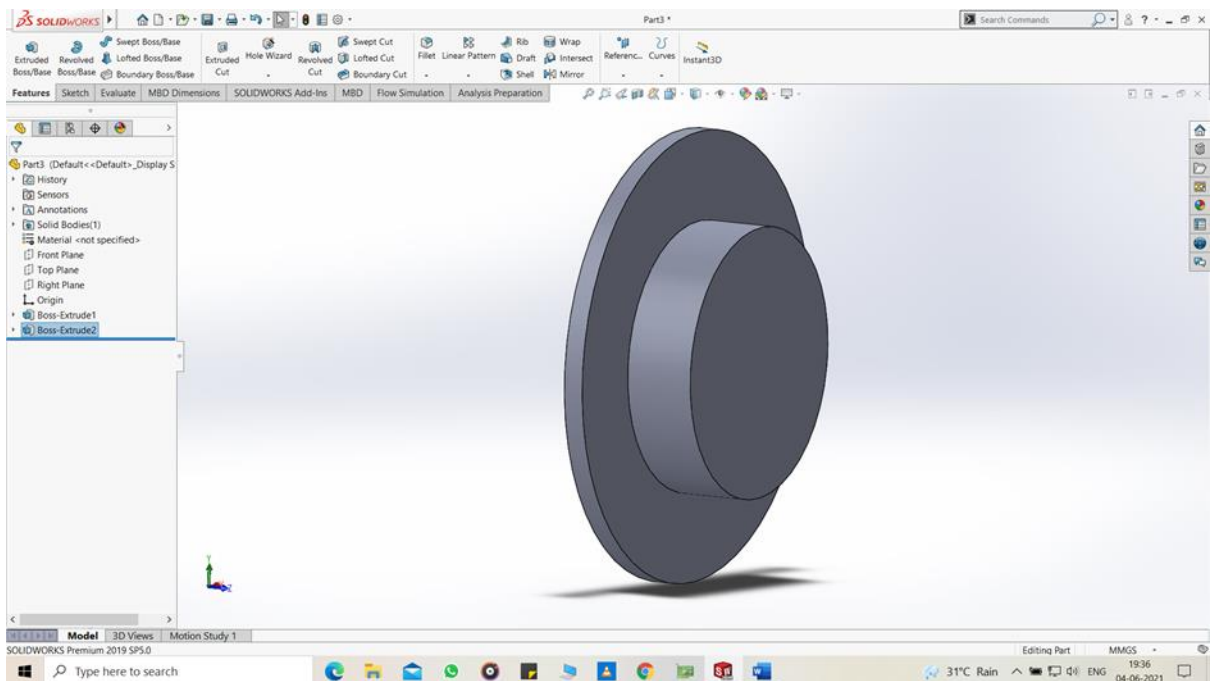


Fig 4.7 Boss extrude

5. Draw another circle by selecting the back phase of the plane with 123mm diameter by using circle command and smart dimensions. Then click on extrude cut through all.

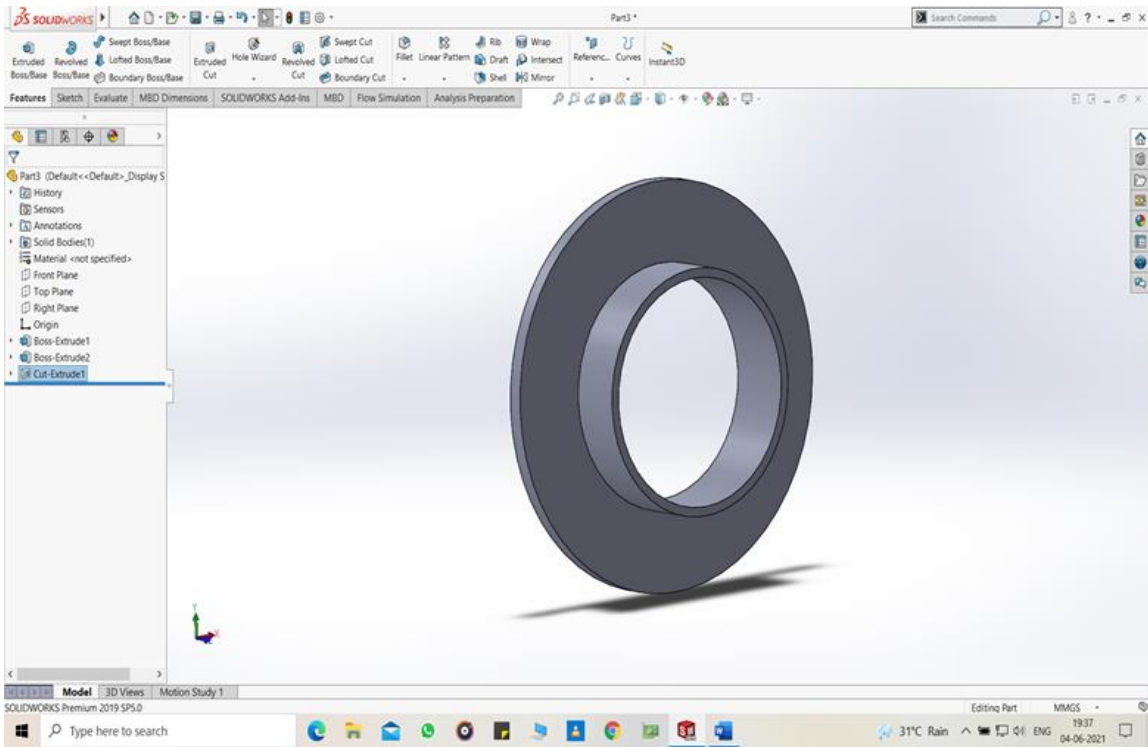


Fig 4.8 Cut extrude

6. Select reference plane reduce the gap to zero.

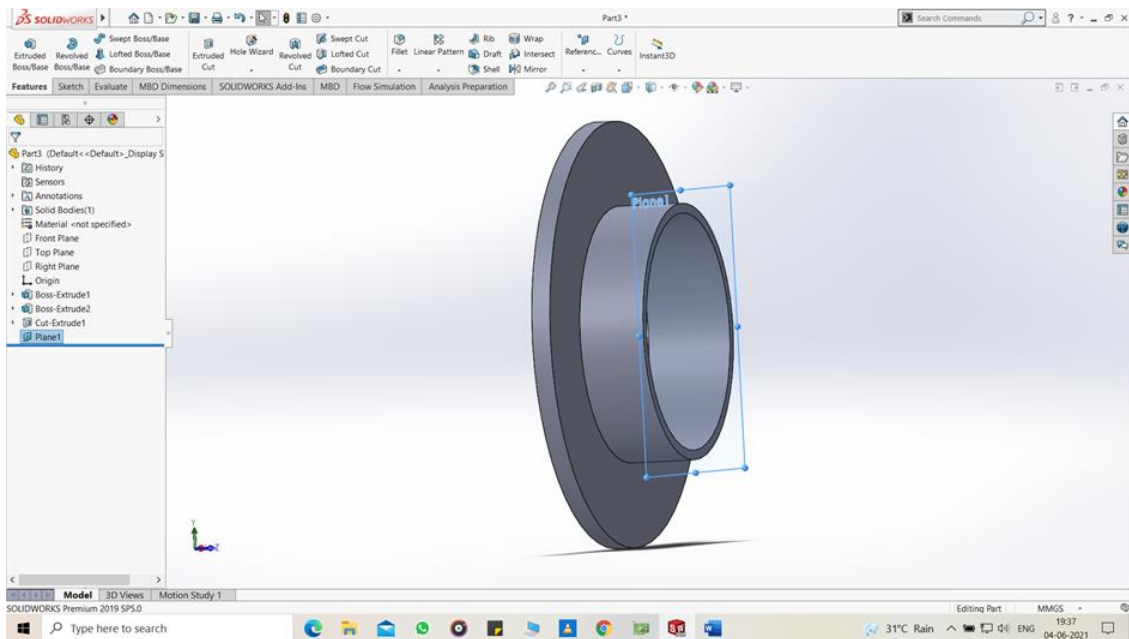


Fig 4.9 selection of reference plane

- Now create a circle on new plane with diameter 133mm using smart dimensions, and extrude it to 8mm by using extrude boss command (not merge).

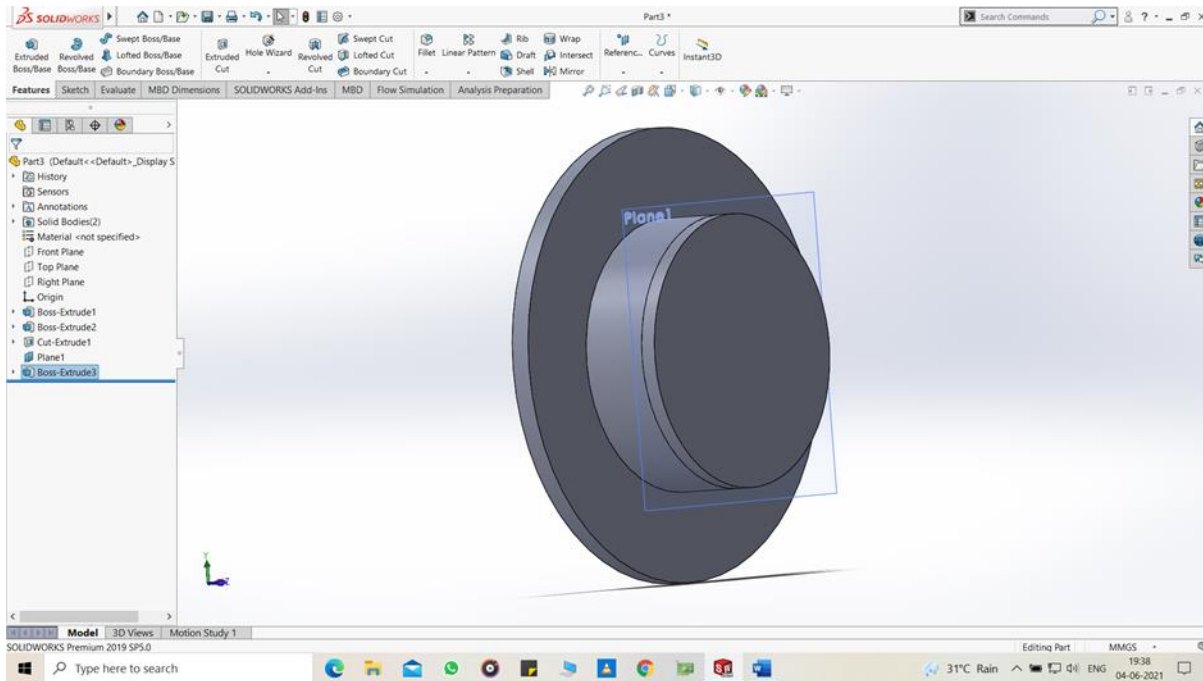


Fig 4.10 Boss extrude

- Now draw a circle with diameter 60mm on the extruded face, then select extrude cut through all.

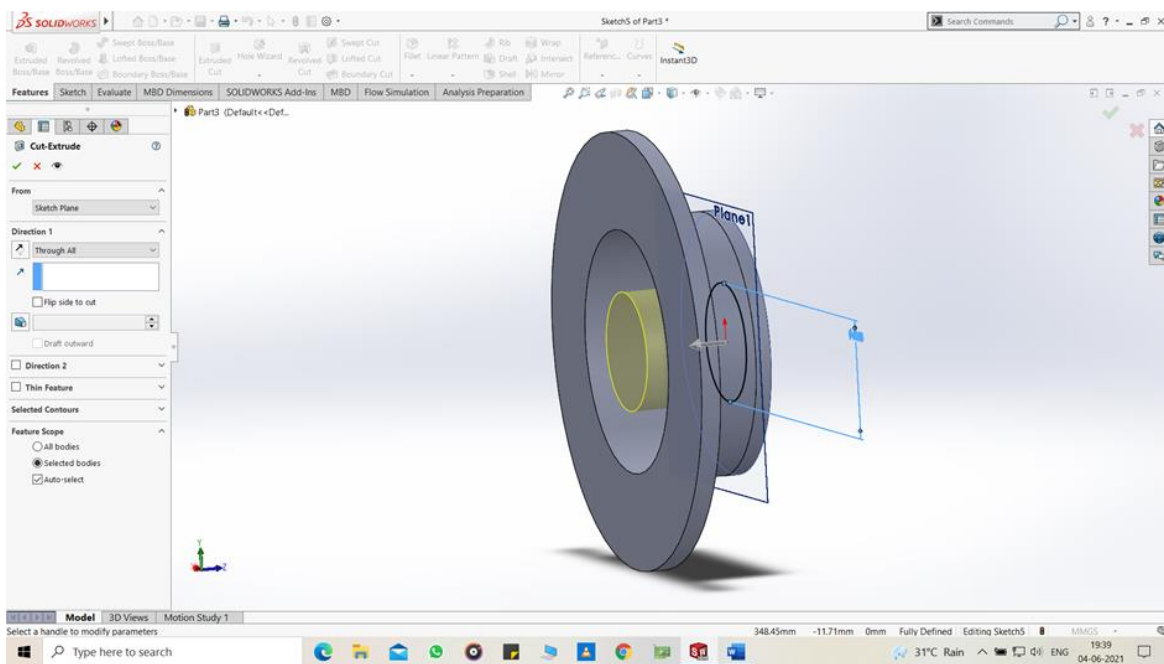


Fig 4.11 cut extrude

9. Draw 4 circles on the same surface with 10mm diameter using circle and smart dimensions command at 50mm distance from center.

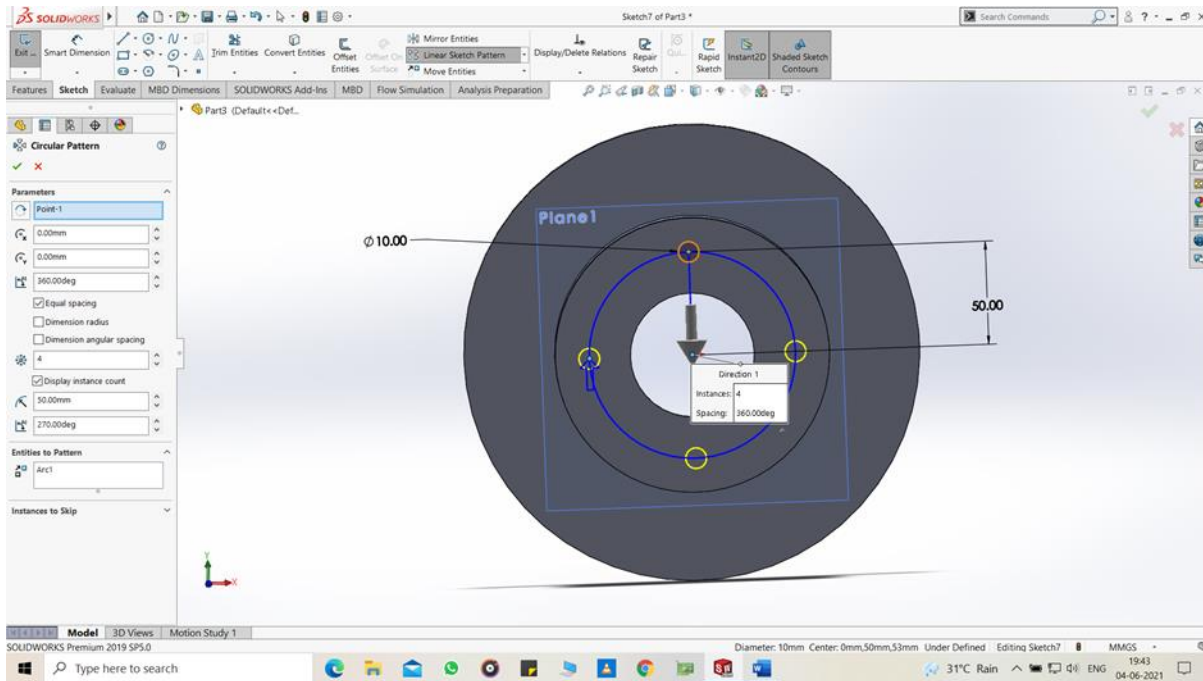


Fig 4.12 creating symmetric circles

10. Now extrude cut all the 4 circles.

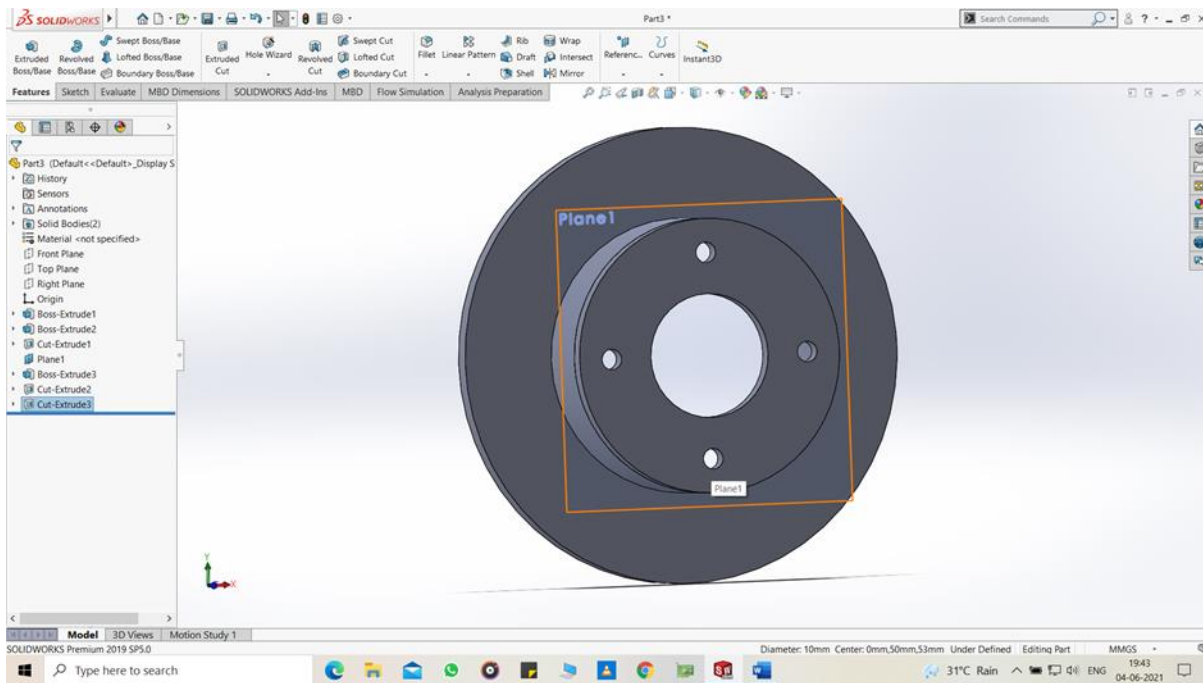


Fig 4.13 cut extrude

4.3 Calculations:

Here, presenting the work for disc brake of MARUTI Company for stress reduction studies.

- Model No : ALTO 800 (Disc Brake)
- Type : Plain Brake
- Kerb weight : 695 kg (Vehicle)
- Max speed : 120 km/h (Vehicle)

Table 4.2 Vehicle specifications

Parameter Name	Parameter Value (units)
Mass of the vehicle (M)	1140 kg
Top speed	120 km/hr or 33.33 m/s
Wheel diameter	540 (mm)
Wheelbase	2360 (mm)
Rim diameter	304.8 (mm)
Body length, breadth & height	3495, 1475, 1460 (mm)

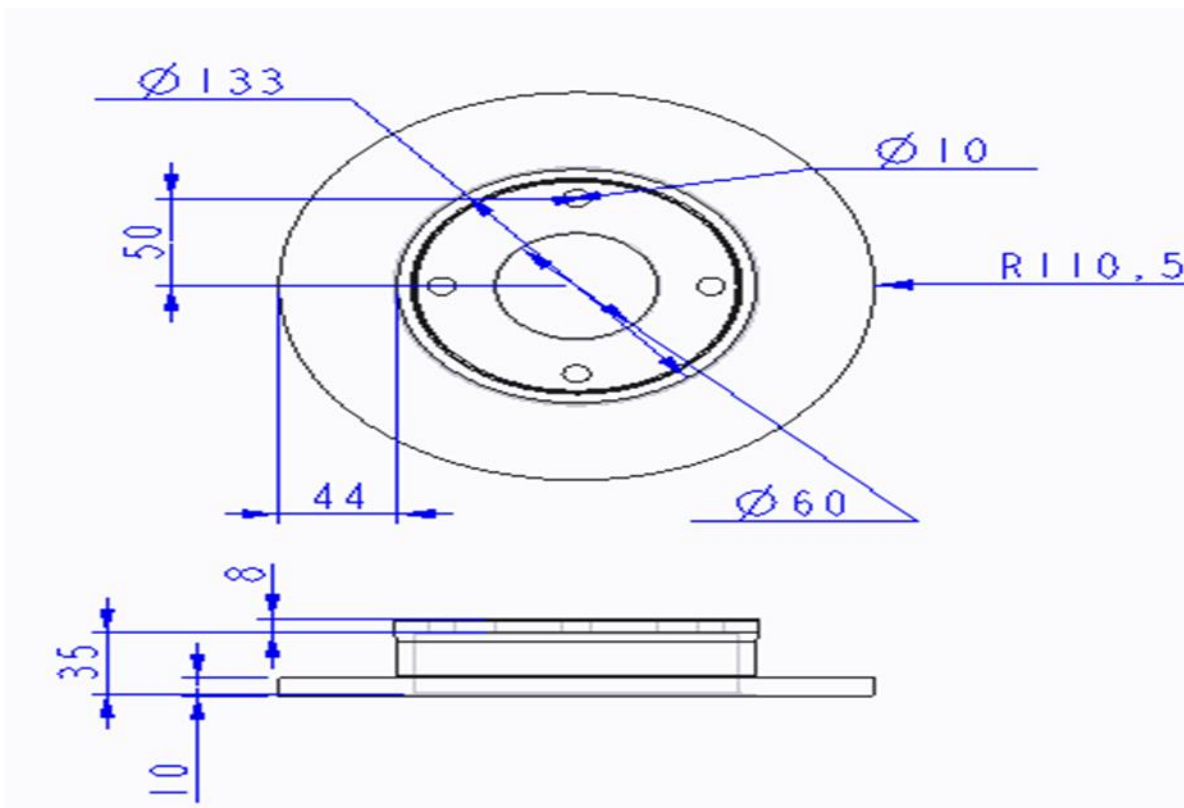


Fig 4.14 Top and side view of rotor

Table 4.3 Dimensions of disc brake rotor

Parameter Name	Parameter Value
Outer diameter of the rotor disc	221 mm
Inner diameter of rotor disc	133 mm
Hole diameter	60 mm
Thickness of rotor disc	10 mm
Calliper piston diameter	44 mm
Mass of disc	2.9 Kg

Kinetic energy of vehicle

$$\begin{aligned}
 \text{K.E} &= (M \times V^2) / 2 \\
 &= (1140 \times 33.33^2) / 2 \\
 &= 633206.7 \text{ joule}
 \end{aligned}$$

Where K.E – Kinetic energy(J).

M – Mass of vehicle(kg).

V – linear velocity of vehicle(m/s).

Stopping distance of vehicle

$$\begin{aligned}
 \text{The maximum friction force } F &= \mu \times M \times g \\
 &= 0.7 \times 1140 \times 9.81 \\
 &= 7828.4 \text{ N}
 \end{aligned}$$

Hence deceleration of the vehicle $a = F/M$

$$\begin{aligned}
 &= 7828.4 / 1140 \\
 &= 6.9 \text{ m/s}^2
 \end{aligned}$$

Time taken to stop vehicle $t = V/a$

$$\begin{aligned}
 &= 33.33 / 6.9 \\
 &= 4.38 \text{ s} \\
 &\approx 5 \text{ s}
 \end{aligned}$$

Heat flux

Heat generated when applying braking action on disc brake = Kinetic energy

$$H_g = KE$$

$$H_g = 633206.7 \text{ joule}$$

Also, heat generated is $H_g = m_d \times C_p \times \Delta t$

$$633206.7 = 2.8 \times 586 \times \Delta t$$

$$\therefore \Delta t = 385.91^\circ\text{C}$$

Where, m_d – mass of disc (kg)

C_p – Specific heat (J/kg-K)

Δt – temperature difference ($^\circ\text{C}$)

Where, $\Delta t = (t_f - t_i)$

$$385.91 = t_f - 25$$

$$t_f = 410.91^\circ\text{C}$$

$$\approx 411^\circ\text{C}$$

As Kinetic energy is entirely converted for 5 sec the power produced will be

$$P = K.E/t$$

$$= 633206.7/5$$

$$= 126.64 \text{ KW}$$

Since only 60% of the mass of the vehicle will be on the front, the power is reduced

$$= (126.64 \times 0.60)/2$$

$$= 38 \text{ KW}$$

Now power on each front rotor is $P = 38/2$

$$= 19 \text{ KW}$$

Where $A = 2 \times$ Contact area of piston of caliper

$$= 2 \times \pi/4 [(diameter \text{ of rotor})^2 - (diameter \text{ of rotor} - diameter \text{ of piston})^2]$$

$$= 2 \times \pi/4 [(0.221)^2 - (0.221 - 0.044)^2]$$

$$= 0.0275 \text{ m}^2$$

$$\text{Heat flux } q = (p/t)/A$$

$$= (19/5)/0.0275$$

$$= 138.18 \text{ KW/m}^2$$

5. BRAKE ROTOR ANALYSIS

When a vehicle is in motion, it is said to have kinetic energy. Brakes are designed to stop the vehicle by absorbing the kinetic energy of the vehicle and dissipating it in the form of heat.

The kinetic energy of a vehicle is given by the following equation:

$$KE = \left(\frac{1}{2}\right)mv^2$$

Where m is the mass of the vehicle and v is the velocity of the vehicle. If the mass of the vehicle is large, or the velocity is large, this can amount to a large amount of energy dissipated in the form of heat. The braking mechanism must be able to withstand both the temperatures generated by this heating as well as the forces incurred during braking.

Now we investigate the design of the braking rotor. The vehicle will be moving at full speed and will be braked to a complete stop. First, a thermal analysis will be run to calculate the temperature distribution in the brake rotor during braking.

1. Open Brake Rotor Assembly.

Click **File**, **Open** and select the assembly Brake Rotor Assembly. Click **Open** to open the assembly.

Activate the configuration called Split Line. It contains the model with necessary changes so that we can run the analysis properly.

2. Start SolidWorks Simulation.

Click **Tools**, **Add-Ins**. Select **SolidWorks Simulation**.

Click **OK**.

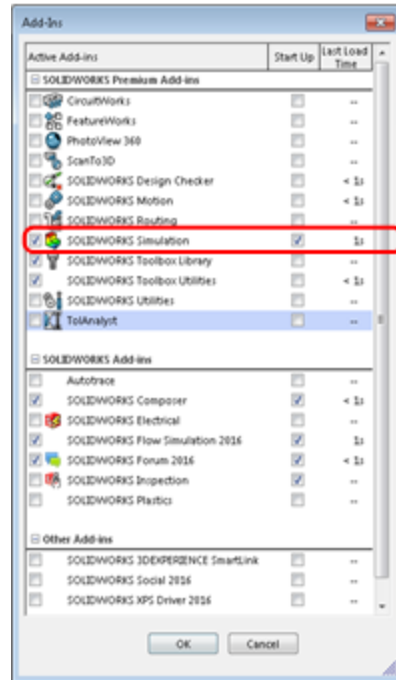


Fig 5.1 selection of solidworks simulation

Solidworks simulation interface:

SolidWorks Simulation functions are accessed in the same way as SolidWorks. When a simulation study is created, a Simulation Study tree appears beneath the Feature Manager design tree. Each new study that gets created is represented by a tab at the bottom of the screen. Like SolidWorks functions, Simulation functions can be accessed from the Simulation toolbar, Command Manager, or Simulation drop-down menu. Additionally, functions can be selected by right-clicking geometry or items in the Simulation Study tree.

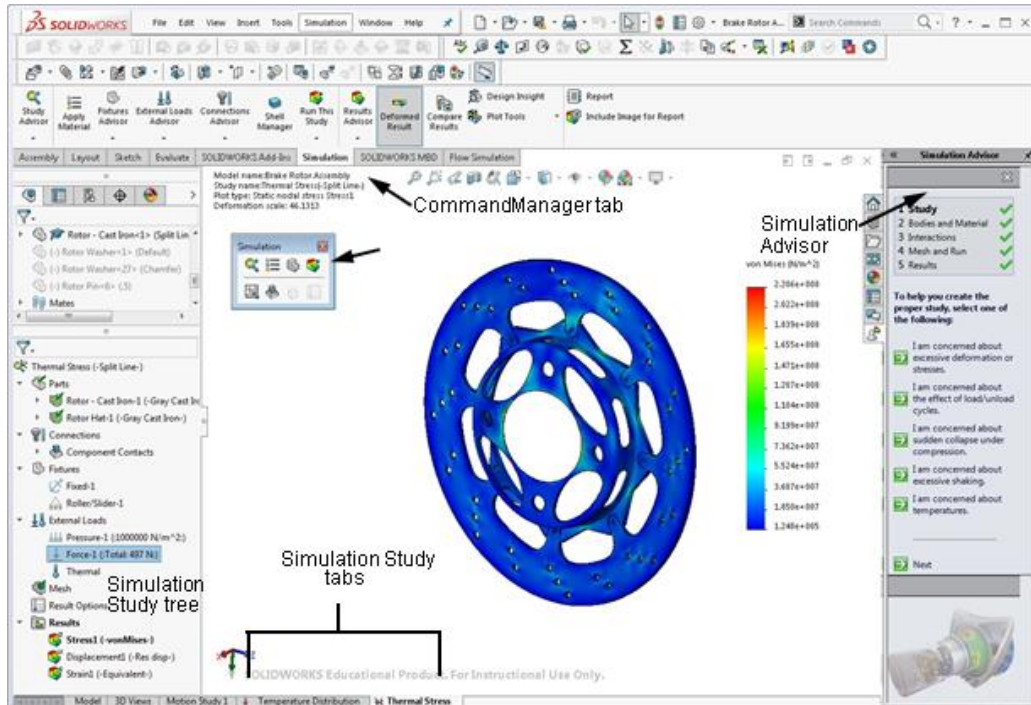


Fig 5.2 Solidworks simulation interface

3. Create a study.

From the **Simulation** drop-down menu, select **Study**.

Select **Thermal** as the **Type**.

Enter Temperature Distribution as the Name. Click **✓**.

The Feature Manager design tree will split and a Simulation study tree will be created below the FeatureManager design tree.

The setup of the study is done using the Simulation study tree.

4. Adjust study properties.

Right-click the study name at the top of the Simulation study tree and select **Properties**.

Under **Options**, select **Transient** and enter **5 sec** as the Total time.

Click **OK**.

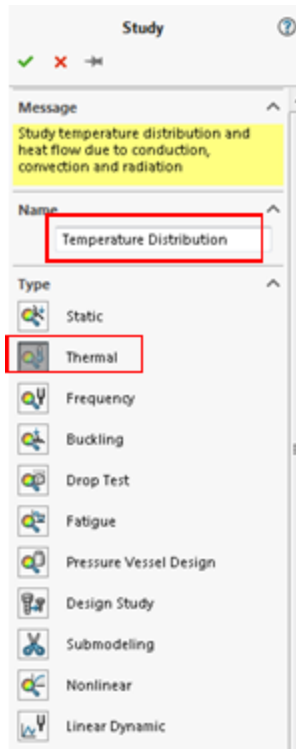


Fig 5.3 Selecting thermal type

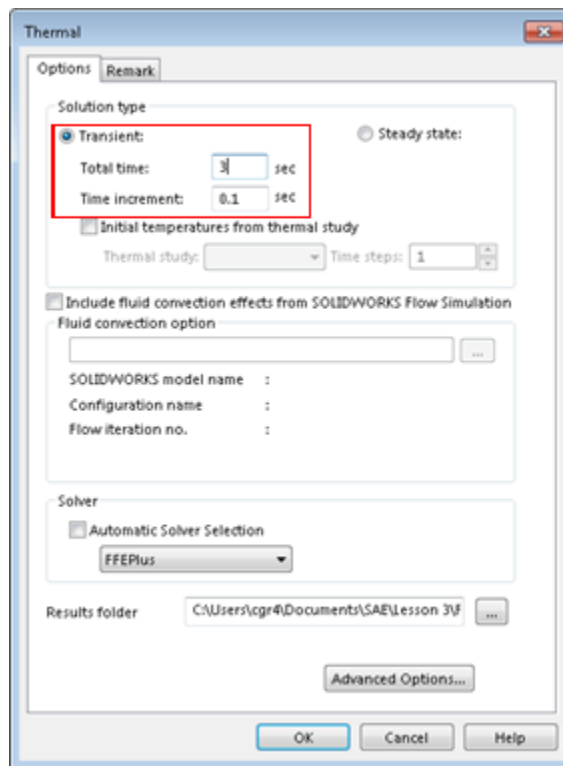


Fig 5.4 Adjusting study properties

5. Apply material.

Right-click the Parts folder and select **Apply Material to All**.

Select Grey Cast Iron under Iron as the material. Click **Apply**, then **Close**.

Thermal boundary conditions:

SolidWorks Simulation solves for the temperature distribution in the solid using the conduction equations and boundary conditions applied to the boundaries of the model. SolidWorks Simulation has several thermal boundary conditions that can be applied to thermal studies.

- **Temperature:**

Allows for the definition of a temperature on a certain entity or body.

- **Convection:**

Applies a convection boundary condition to the selected faces. The convection coefficient and ambient temperature are specified and the heat lost due to convection is calculated automatically.

- **Heat flux:**

Applies some amount of heat into a face per unit area.

- **Heat power:**

Applies some amount of heat to a vertex, edge, face or component.

- **Radiation:**

Allows surface-to-surface or surface-to-ambient radiation.

In this model, we will apply convection to all faces because all of the faces will be exposed to the air. In addition, we will apply a heat power to the faces that the brake pads touch.

Convection:

Convection is the transfer of thermal energy between a surface and a fluid. The amount of heat transferred through conduction is proportional to the convection coefficient, h , the surface area, A , and the temperature difference between the surface and the surrounding fluid.

$$Q_{\text{convection}} = hA(T_s - T_f)$$

We will assume a convection coefficient of $90 \text{ W/m}^2\cdot\text{K}$ and an ambient temperature of 20°C , which are approximations. Actual convection coefficients and

ambient temperature could be computed by running a CFD analysis in SolidWorks Flow Simulation or from experiments.

6. Apply thermal load.

Right-click Thermal Loads in the Simulation Study tree and select **Convection**.

Select **Select all exposed faces** in the Convection PropertyManager.

This will choose all of the exposed faces for the convection boundary condition.

Enter **90 W/m².K** as the **Convection Coefficient**.

Enter **293 Kelvin** as the **Bulk Ambient Temperature**.

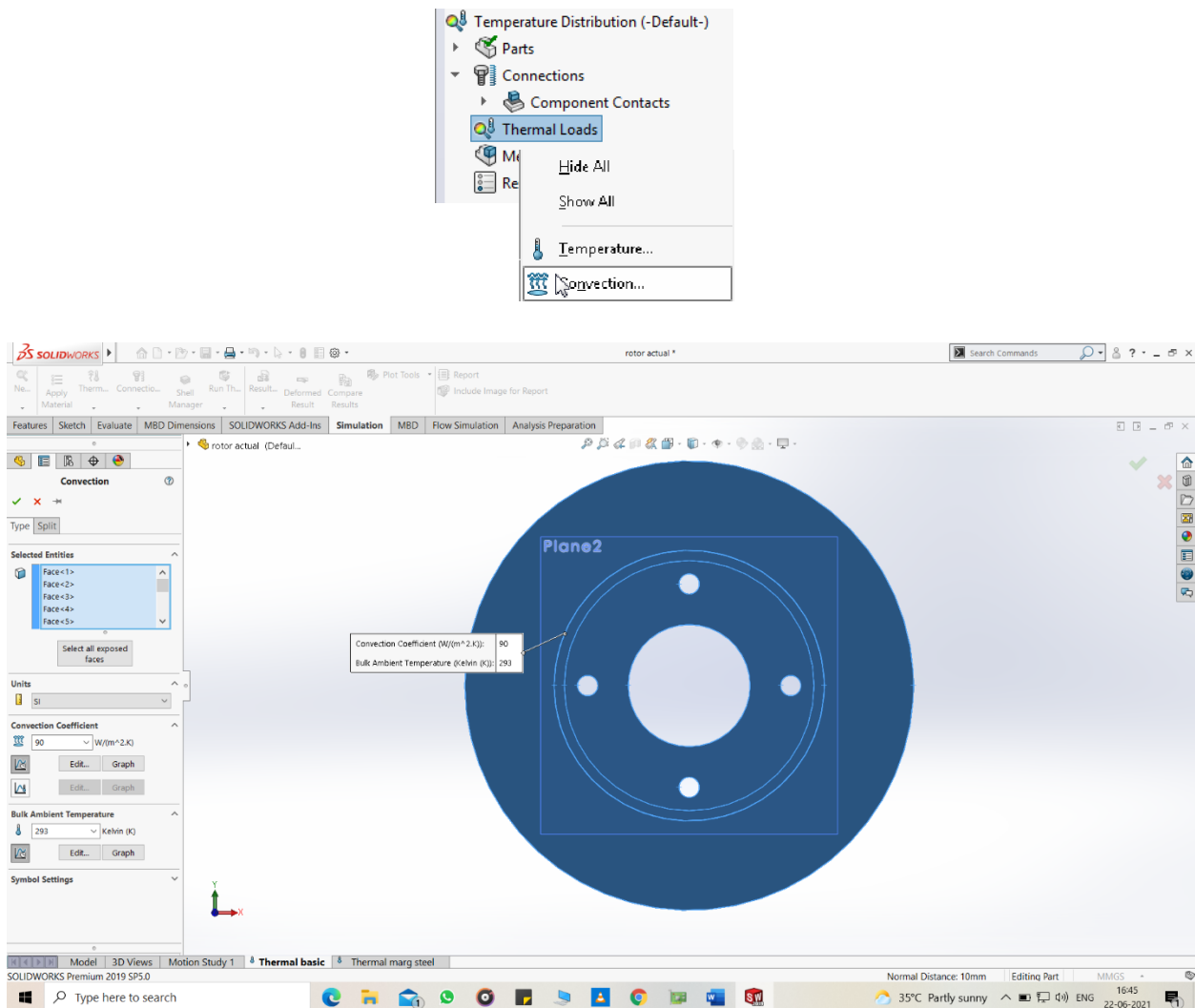


Fig 5.5 thermal load application

7. Edit time curve:

Click **Use time curve** and select **Edit**.

Column **X** denotes the time and column **Y** denotes the multiplication factor that will be applied to the convection coefficient that was entered

Enter **(0, 1)** and **(5, 1)** in the table. This will represent the convection always being turned ON.

Click OK.

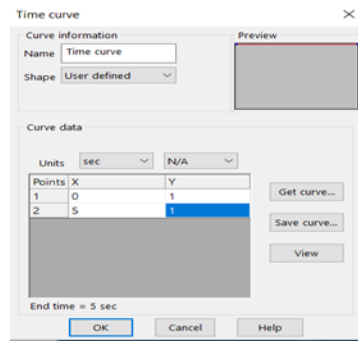


Fig 5.6 time curve edit

Click ✓.

Heat power.

As the vehicle is braked, the rotor is spinning and the brake pads are rubbing against the surface of the rotor, creating friction and heat energy. Much of the kinetic energy of the car is being transferred to thermal energy through the brake pads. The heat power will be applied to the brake rotors in the area that the pads touch.

The amount of heat power can be calculated from the amount of kinetic energy carried by the car. the kinetic energy of the car is as follows:

$$\begin{aligned} \text{K.E} &= (M \times V^2) / 2 \\ &= (1140 \times 33.33^2) / 2 \\ &= 633206.7 \text{ joule} \end{aligned}$$

$$\begin{aligned} \text{Now, Heat power total} &= \text{K.E} / \Delta t \\ &= 126.64 \text{KW} \end{aligned}$$

∴ since only 60% of the mass of vehicle will be on the front, the power is reduced
= [(0.6) x heat power total] / 2 = 38KW

$$\begin{aligned} \text{Now the power on the each front rotor is } p &= 38 / 2 \\ &= 19 \text{KW.} \end{aligned}$$

8. Apply thermal load.

Right-click Thermal Loads in the Simulation Study tree and select **Heat Power**.

Select the four faces of the rotor that the brake pads touch.

Enter **19000W** as the **Heat power**.

Select **Total**.

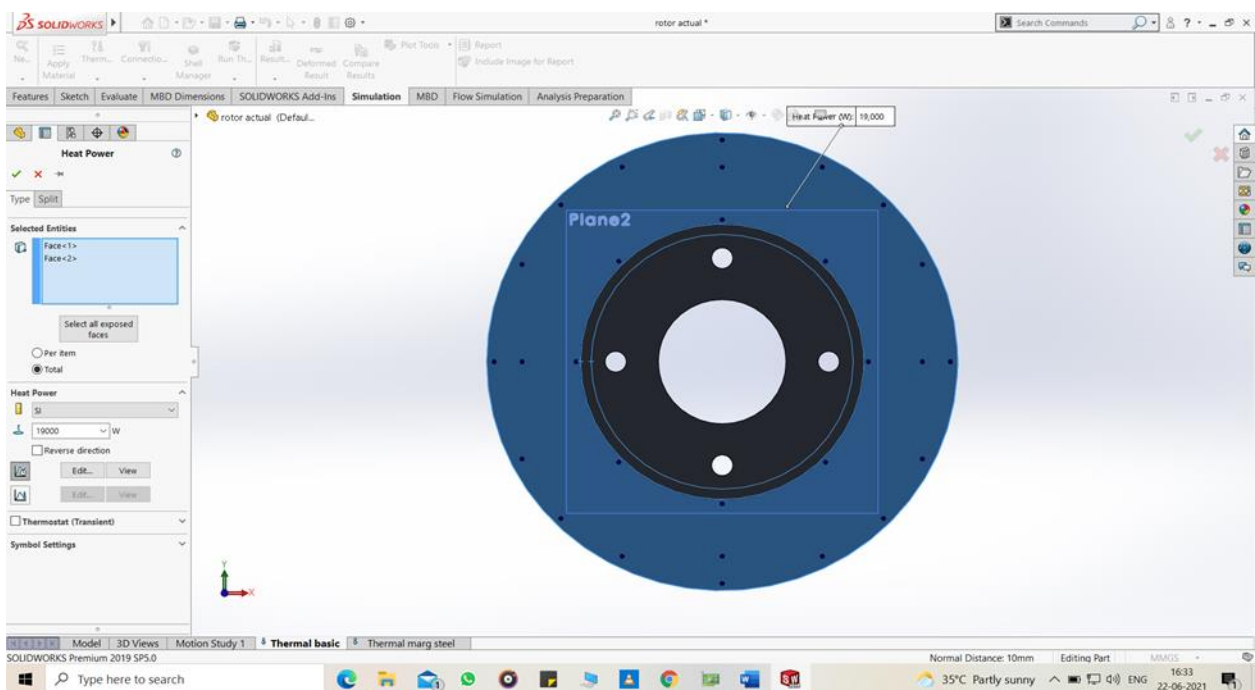


Fig 5.7 thermal load application

9. Edit time curve.

Click **Use Time Curve** and select **Edit**.

Column **X** denotes the time and column **Y** denotes the multiplication factor that will be applied to the heat power that was entered.

Enter **(0, 1)** and **(5, 1)** in the table. This will represent the heat power always being turned ON.

Click **OK**.

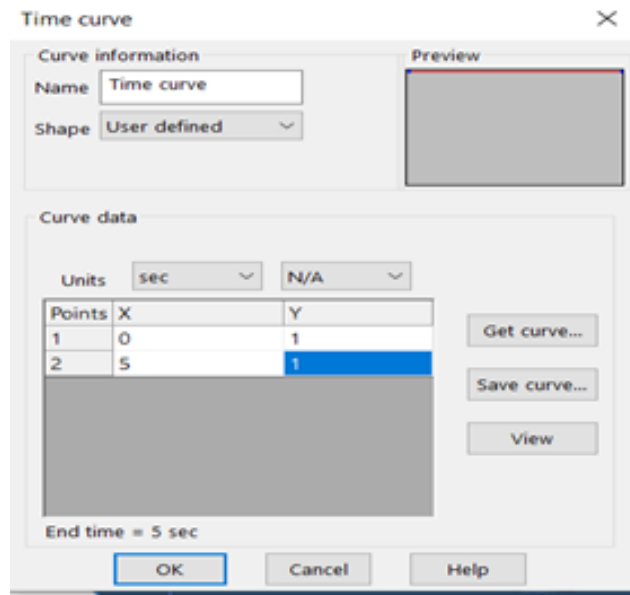


Fig 5.8 time curve edit

Click ✓.

10. Initial temperature.

Right-click Thermal Loads in the Simulation Study tree and select **Temperature**.

Select **Initial temperature**.

Select the assembly from the fly-out FeatureManager design tree.

Enter **25 °C** as the **Temperature**.

Click ✓.

11. Mesh the model.

Right-click Mesh in the Simulation Study tree and select **Create Mesh**. Use **Curvature based mesh** and default element size.

Click ✓.

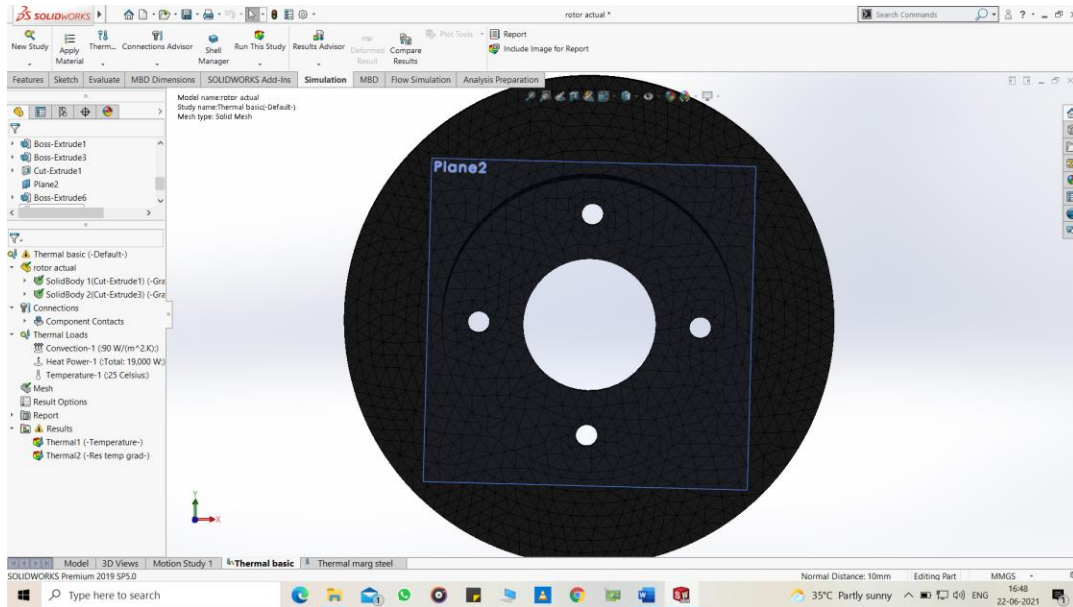


Fig 5.9 mesh application to model

12. Run the study.

Click **Run** from the Simulation drop-down menu.

Now we perform the various post processing options associated with transient thermal analysis.

13. Plot temperature distribution.

Right-click the Thermal1 plot of the temperature distribution and select **Edit Definition**.

Change the **Units** to **Celsius**.

Make sure the plot is set at 50.

Click **✓**.

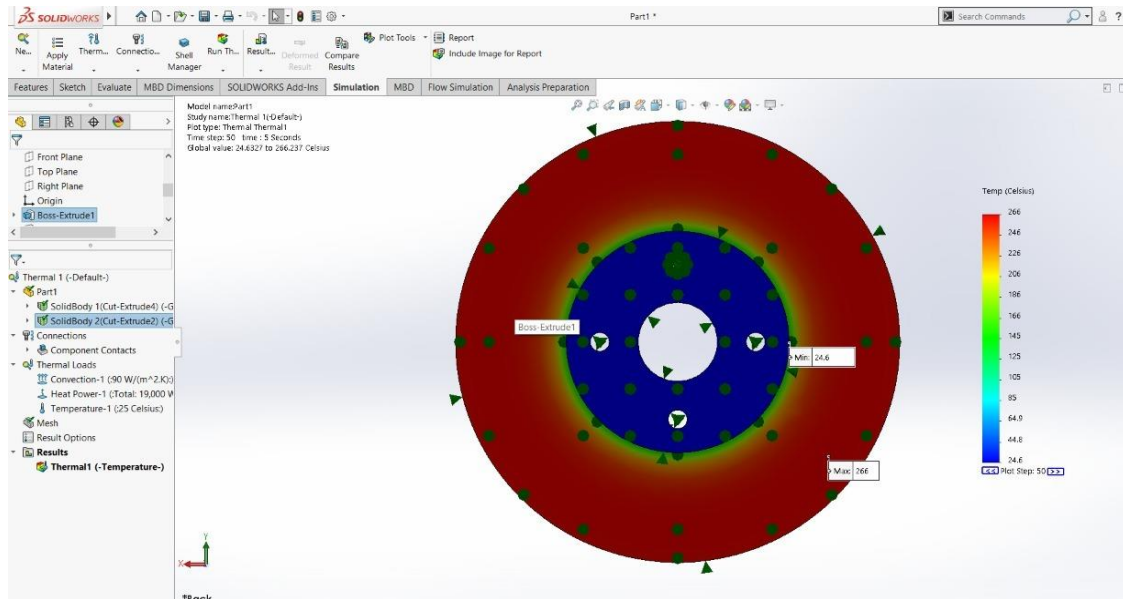


Fig 5.10 Thermal distribution

14. Probe.

Right-click on the temperature plot in the Result folder and select **Probe**.

Select any location on the brake rotor.

Click the **Response** button  under **Report Options**.

A plot of temperature vs time will appear.

Click .

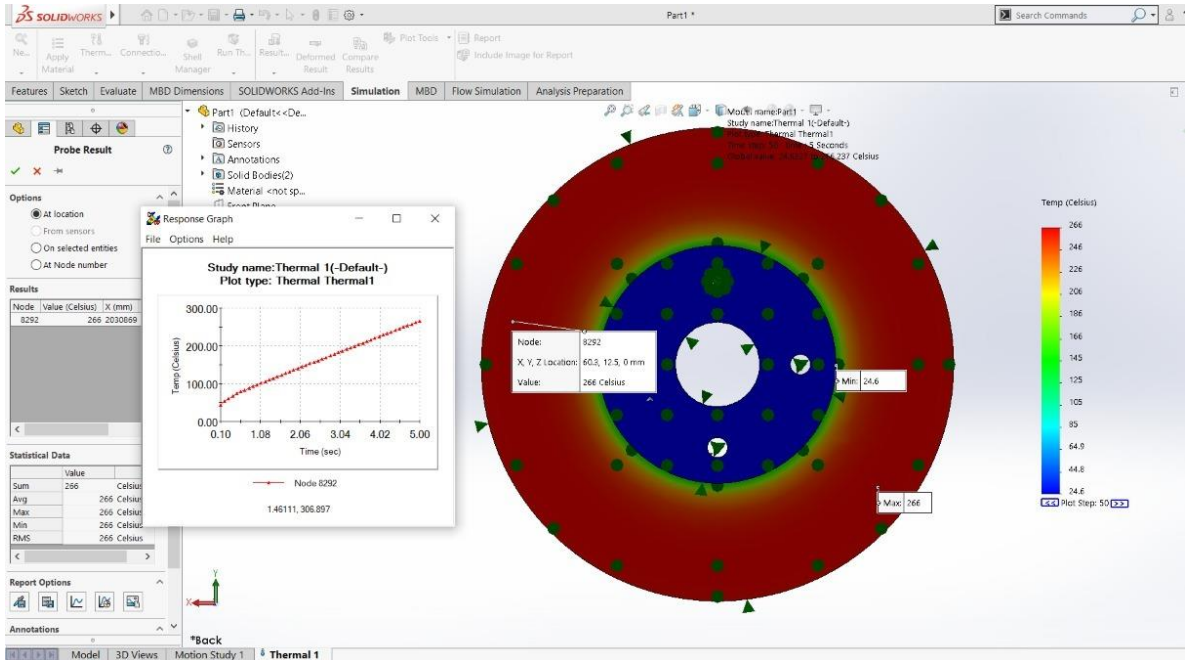


Fig 5.11 Plotting graphs

6. RESULTS AND DISCUSSION:

The result obtained by the actual experimentation and the analysis is checked and the results are interpreted as below. In SOLIDWORKS, the two main solutions are calculated the first one is the temperature and the other is the temperature gradient. The results obtained by SOLIDWORKS are reviewed firstly.

The contour diagrams for the profiles are given as follows. The main advantage of the software analysis is that it discretizes the whole model into a small sized fragments. The boundary conditions are first get applied to the nodes and then the final solution is achieved by the addition of individual node. Thus, the results obtained by the software are more precise than the experimental value. There will be some difference in the experimental value and the software value.

6.1 Results for Grey cast Iron rotor

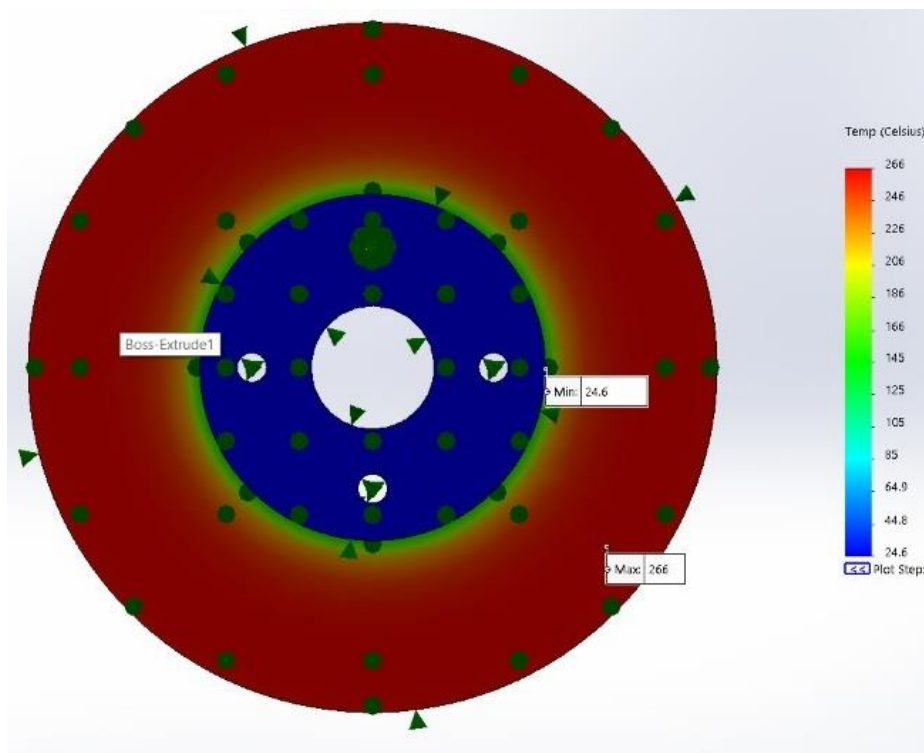


Fig 6.1 Temperature distribution for grey cast iron rotor

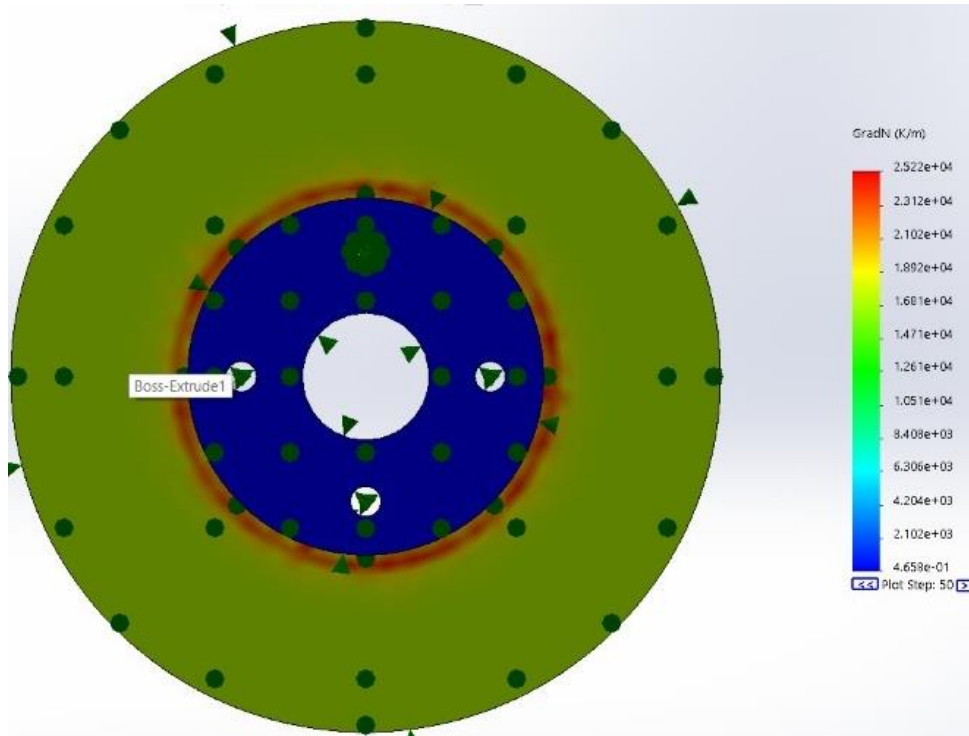


Fig 6.2 Resultant Temperature gradient for grey cast iron rotor

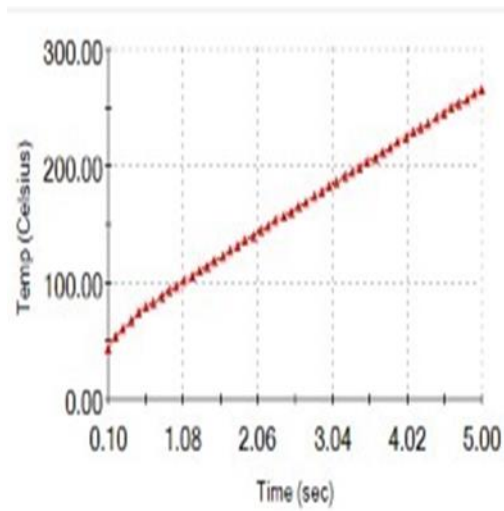


Fig 6.3 Temperature vs time of cast iron rotor

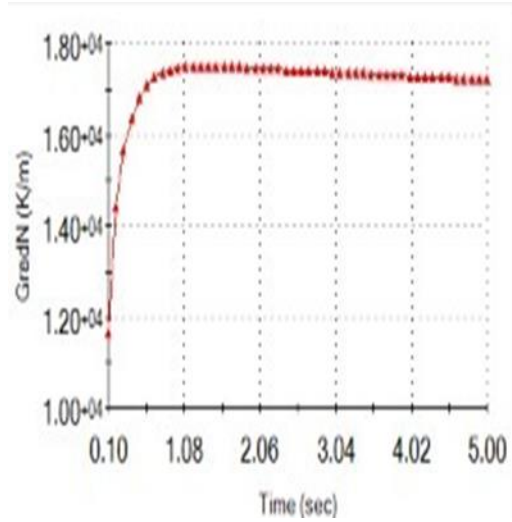


Fig 6.4 Temperature Gradient vs time for cast iron rotor

6.2 Results for Grey cast Iron rotor with copper liner

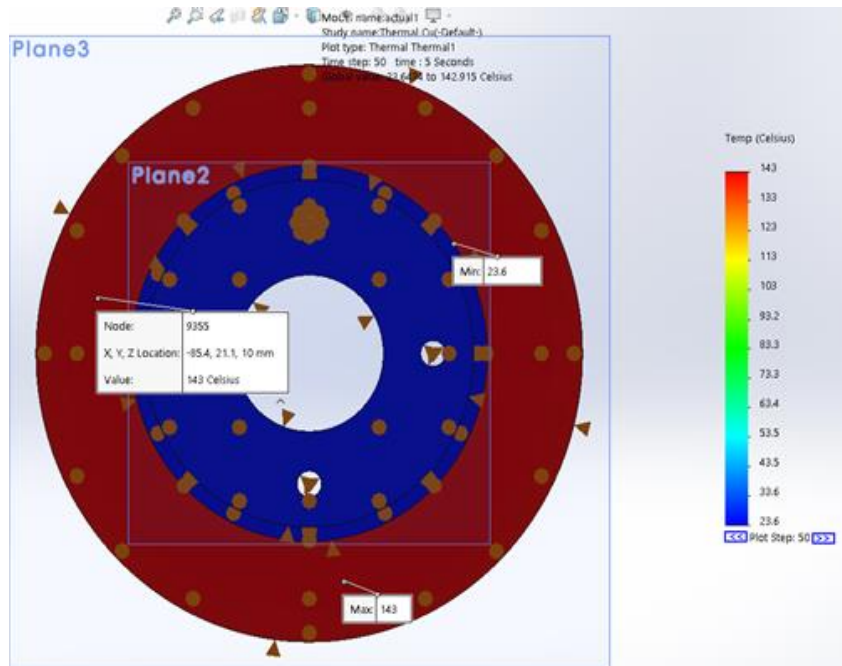


Fig 6.5 Temperature distribution of copper liner

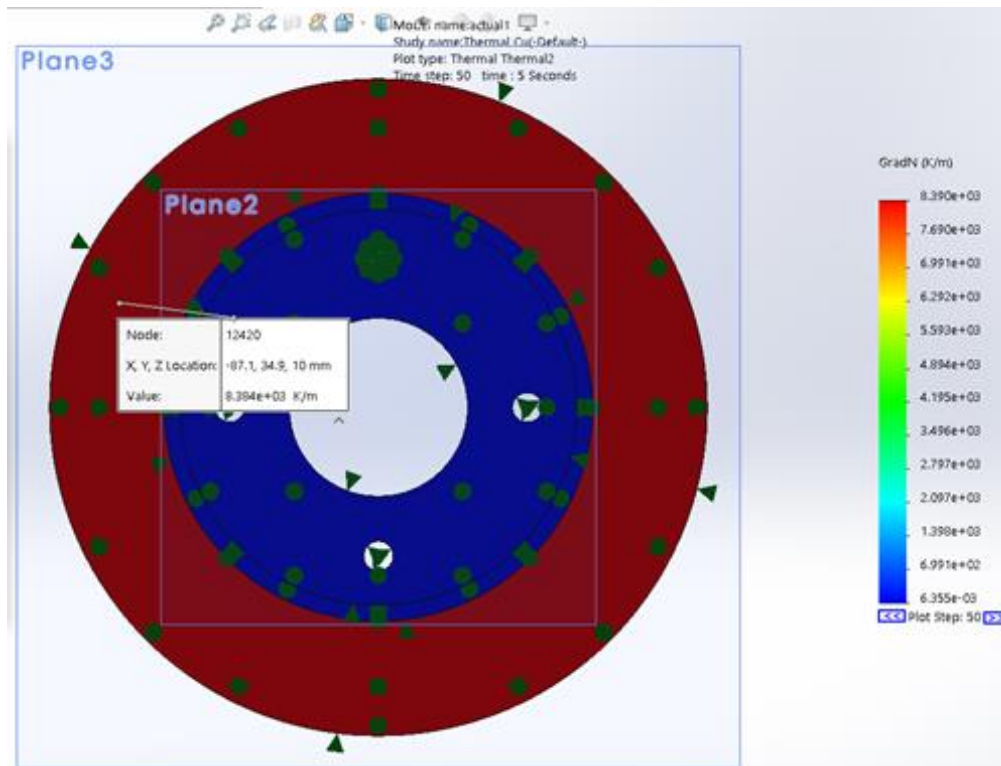


Fig 6.6 Resultant Temperature gradient of copper liner

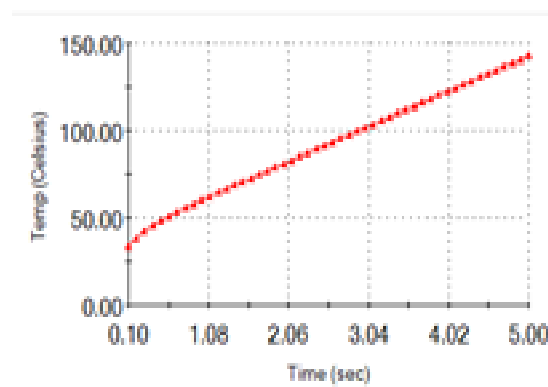


Fig 6.7 Temperature vs time of copper liner

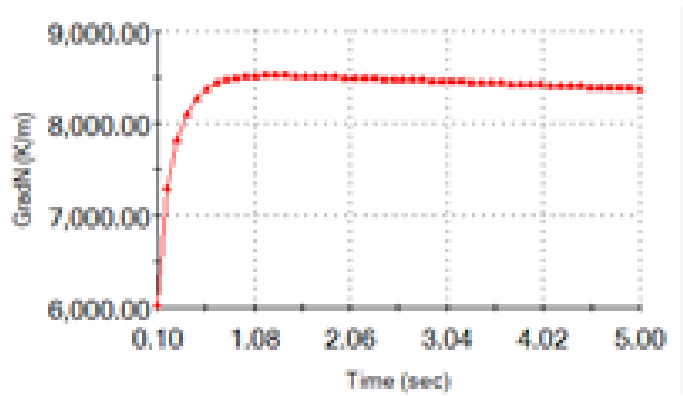


Fig 6.8 Temperature Gradient vs time of copper liner

6.3 Results for Grey cast Iron rotor with steel liner

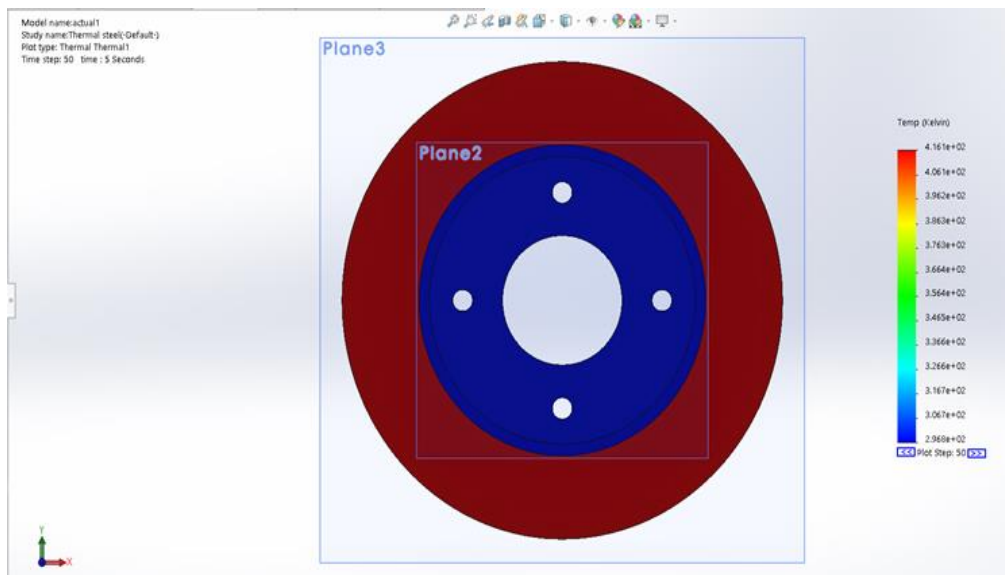


Fig 6.9 Temperature distribution of steel liner

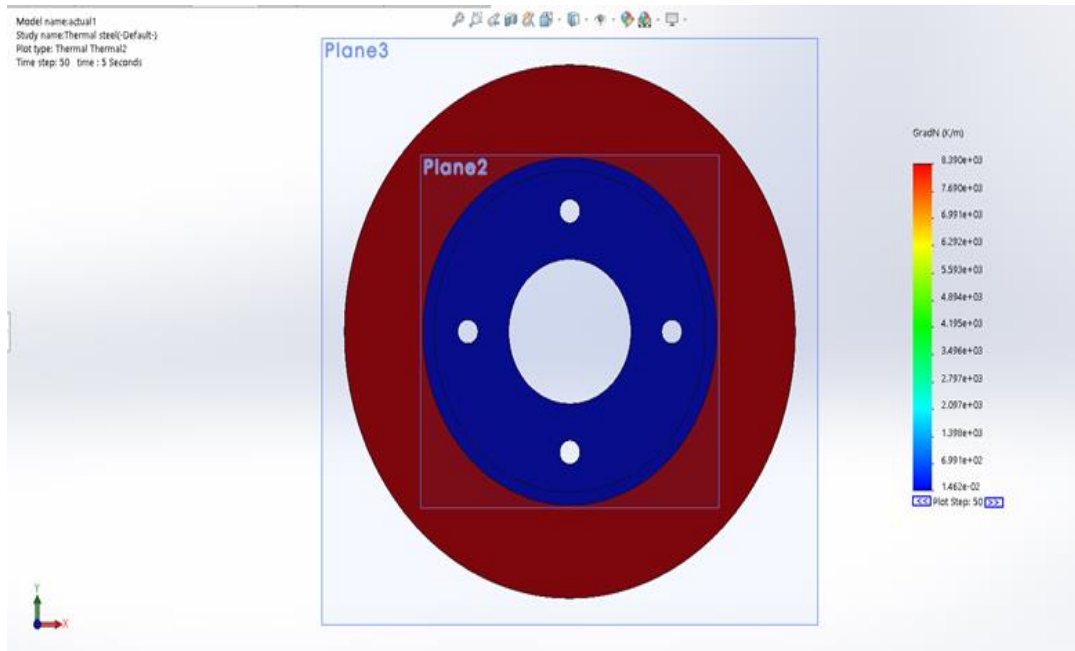


Fig 6.10 Resultant Temperature gradient of steel liner

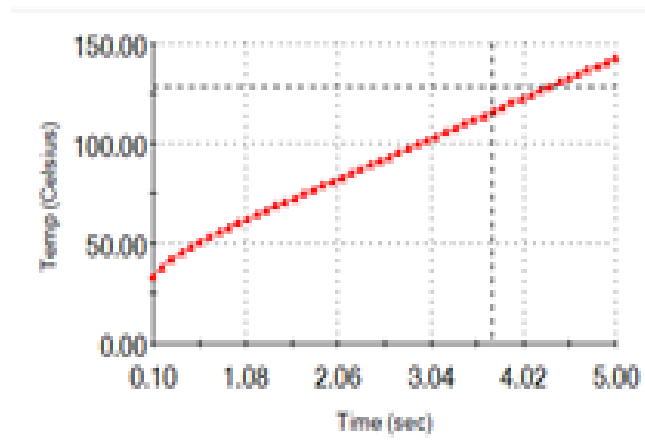


Fig 6.11 Temperature vs time of steel liner

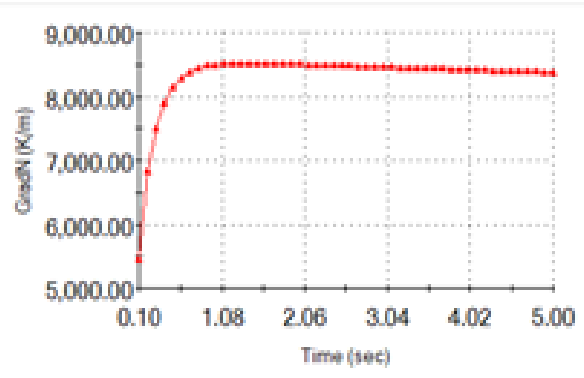


Fig 6.12 Temperature Gradient vs time of steel liner

6.4 Results for Grey cast Iron rotor with silicon liner

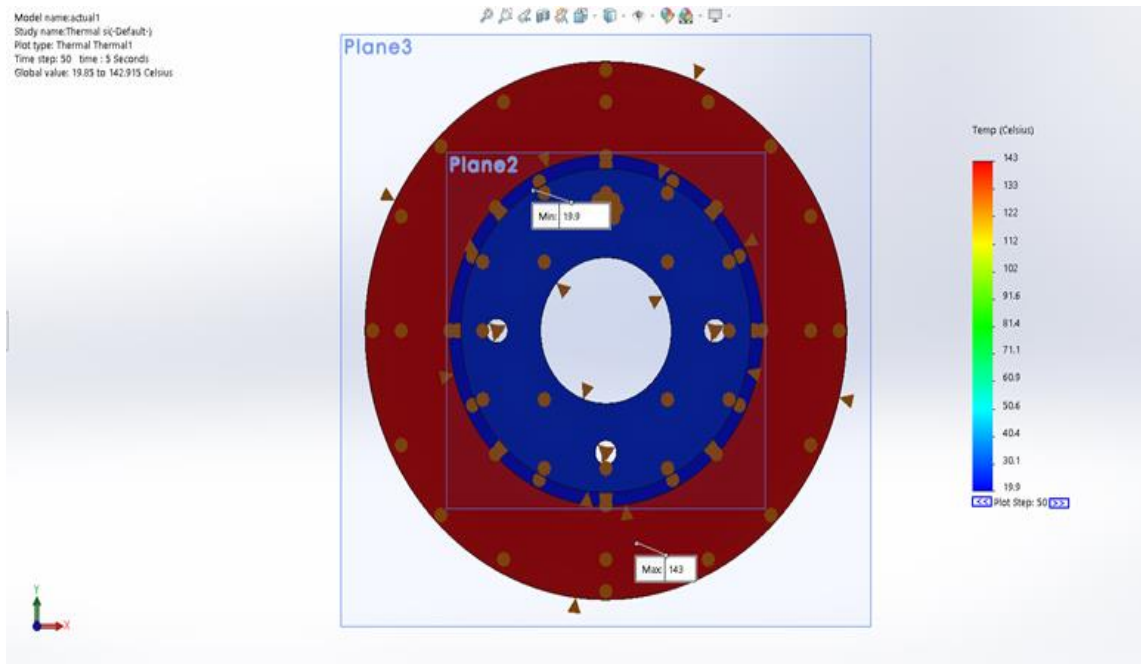


Fig 6.13 Temperature distribution of silicon liner

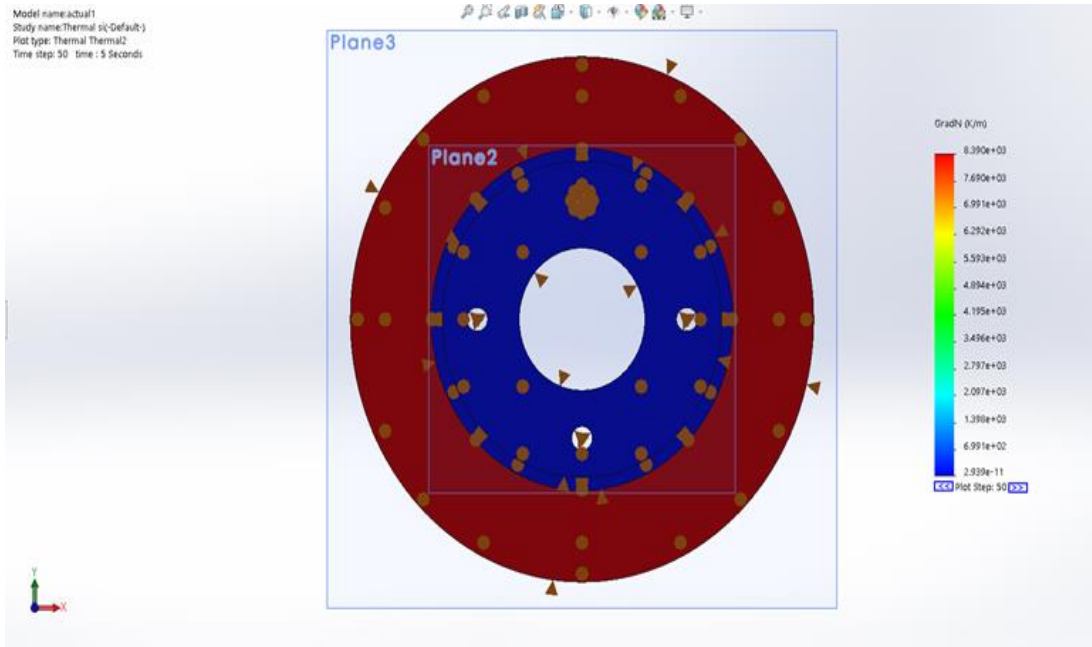


Fig 6.14 Resultant Temperature gradient of silicon liner

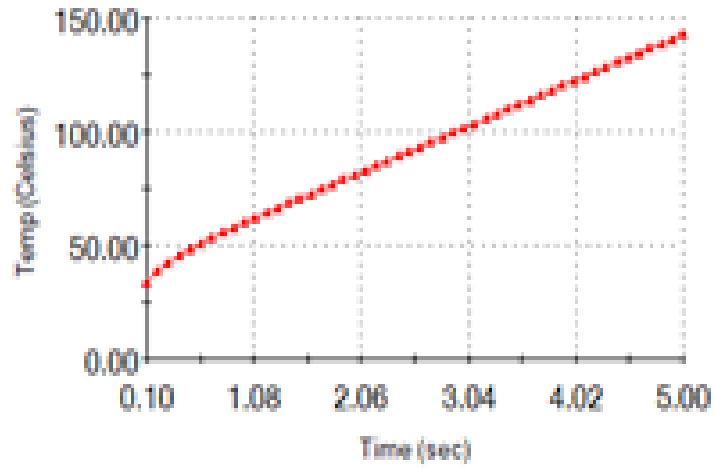


Fig 6.15 Temperature vs time of silicon liner

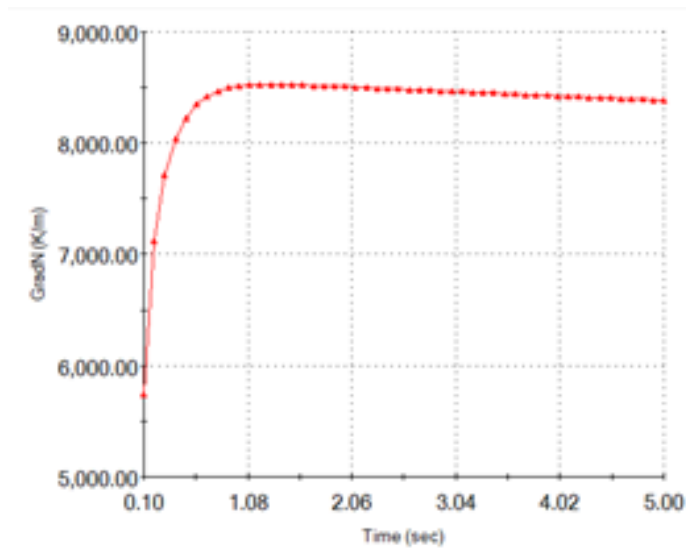


Fig 6.16 Temperature Gradient vs time of silicon liner

6.5 Results for Grey cast Iron rotor with Brass liner

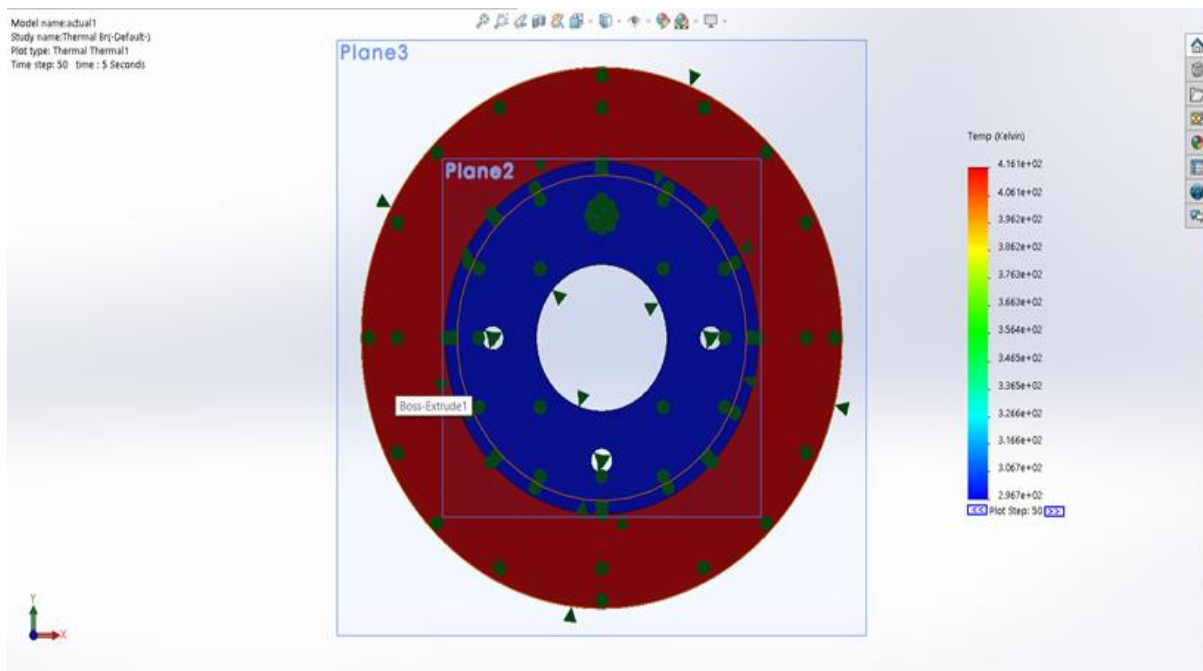


Fig 6.17 Temperature distribution of Brass liner

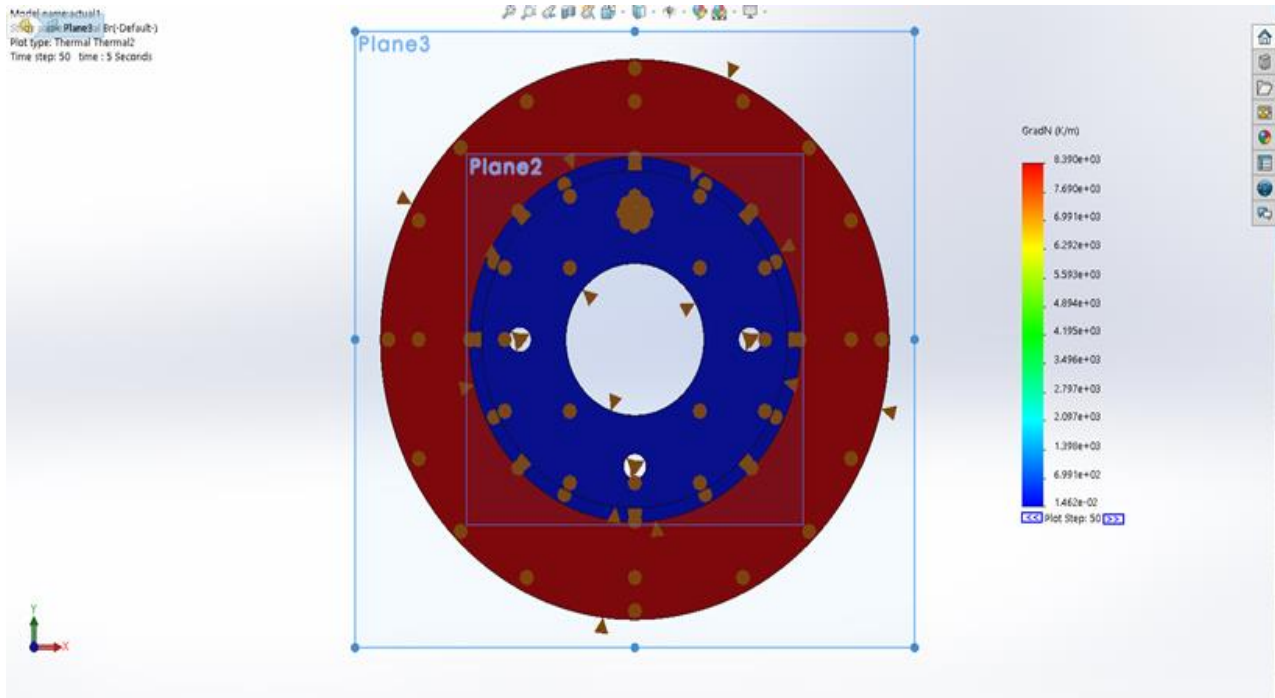


Fig 6.18 Resultant Temperature gradient of Brass liner

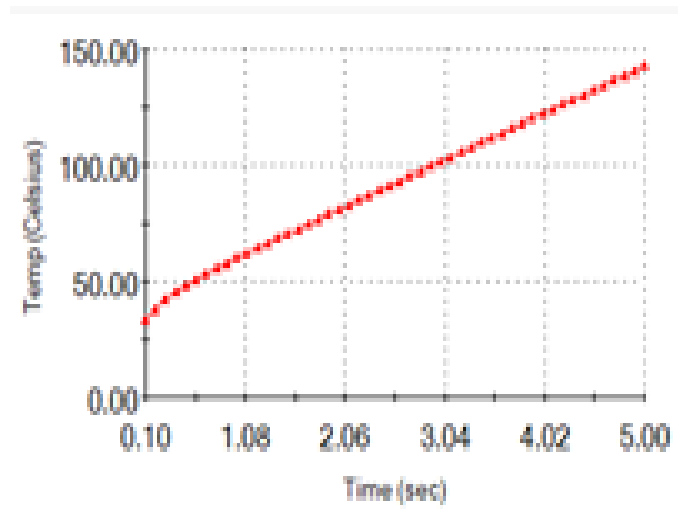


Fig 6.19 Temperature vs time of Brass liner

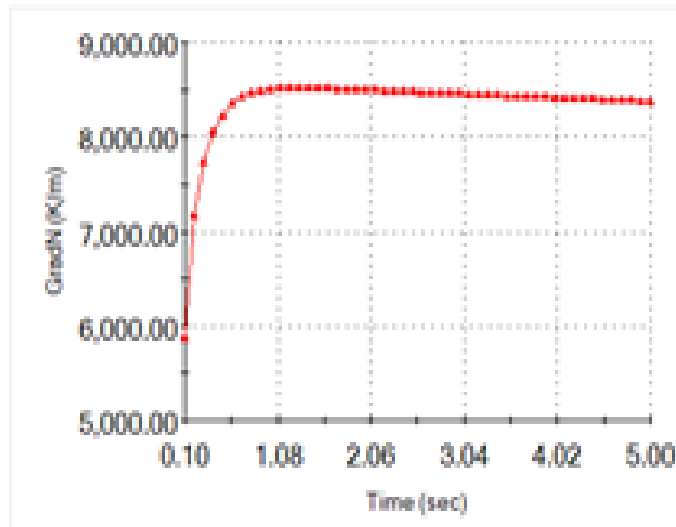


Fig 6.20 Temperature Gradient vs time of Brass liner

6.6 Results for Grey cast Iron rotor with Magnesium liner

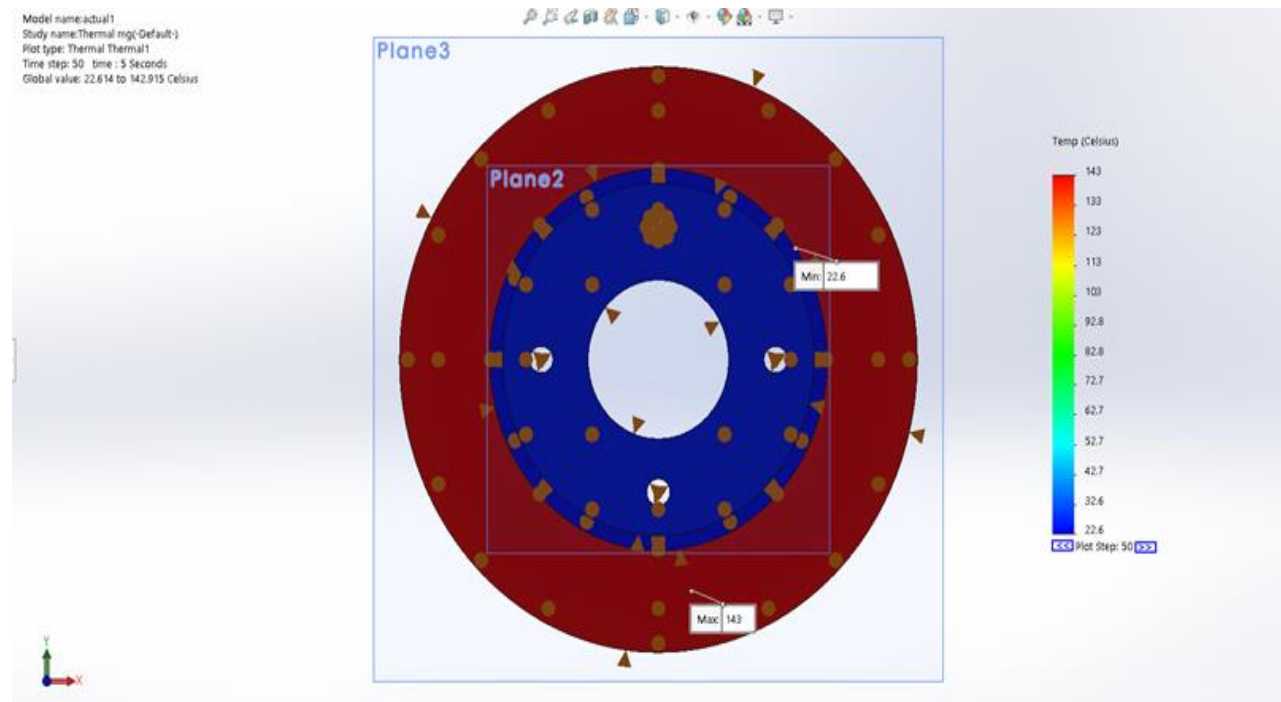


Fig 6.21 Temperature distribution of Magnesium liner

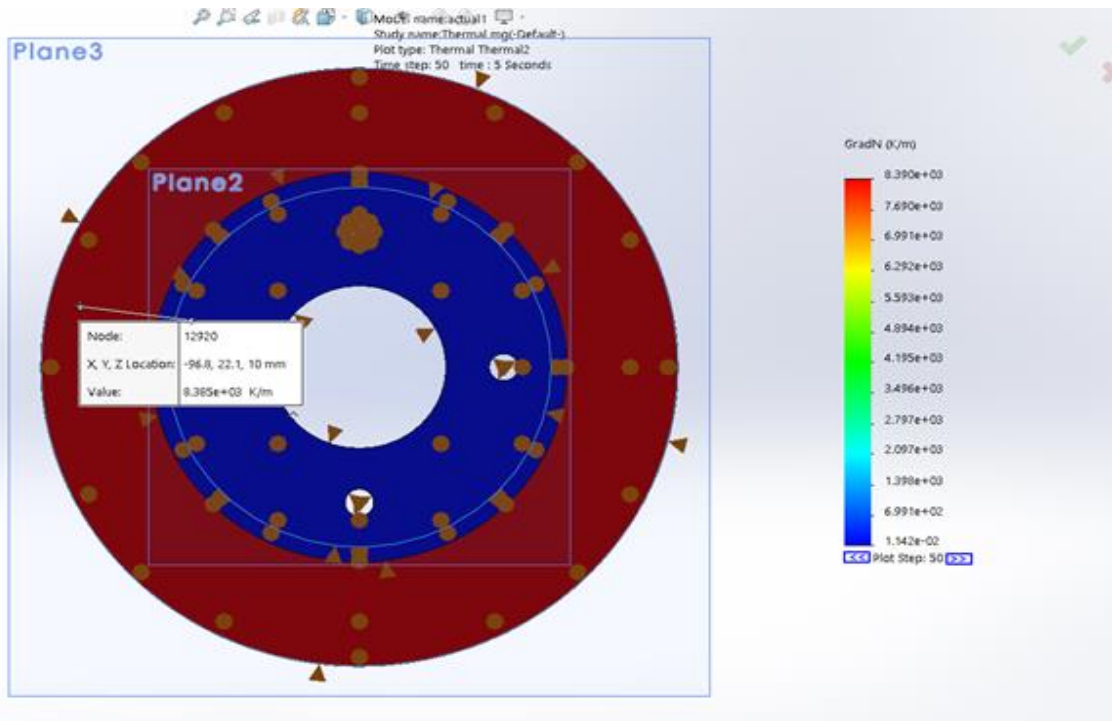


Fig 6.22 Resultant Temperature gradient of Magnesium liner

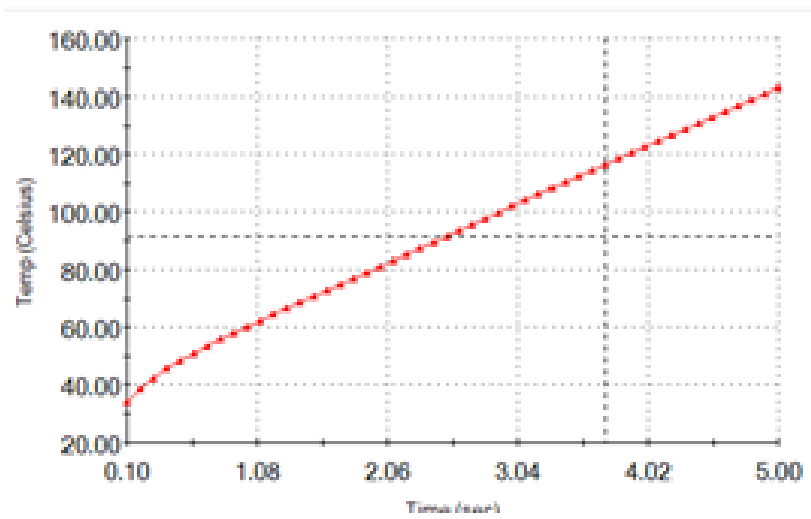


Fig 6.23 Temperature vs time of Magnesium liner

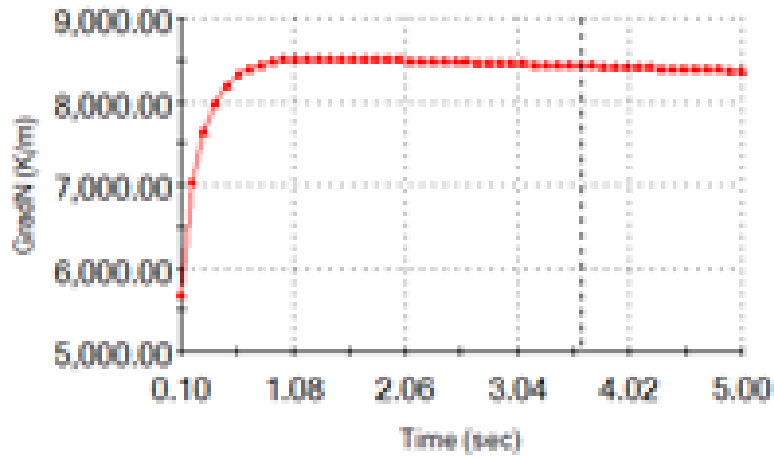


Fig 6.24 Temperature Gradient vs time of Magnesium liner

6.7 Results for Ductile iron

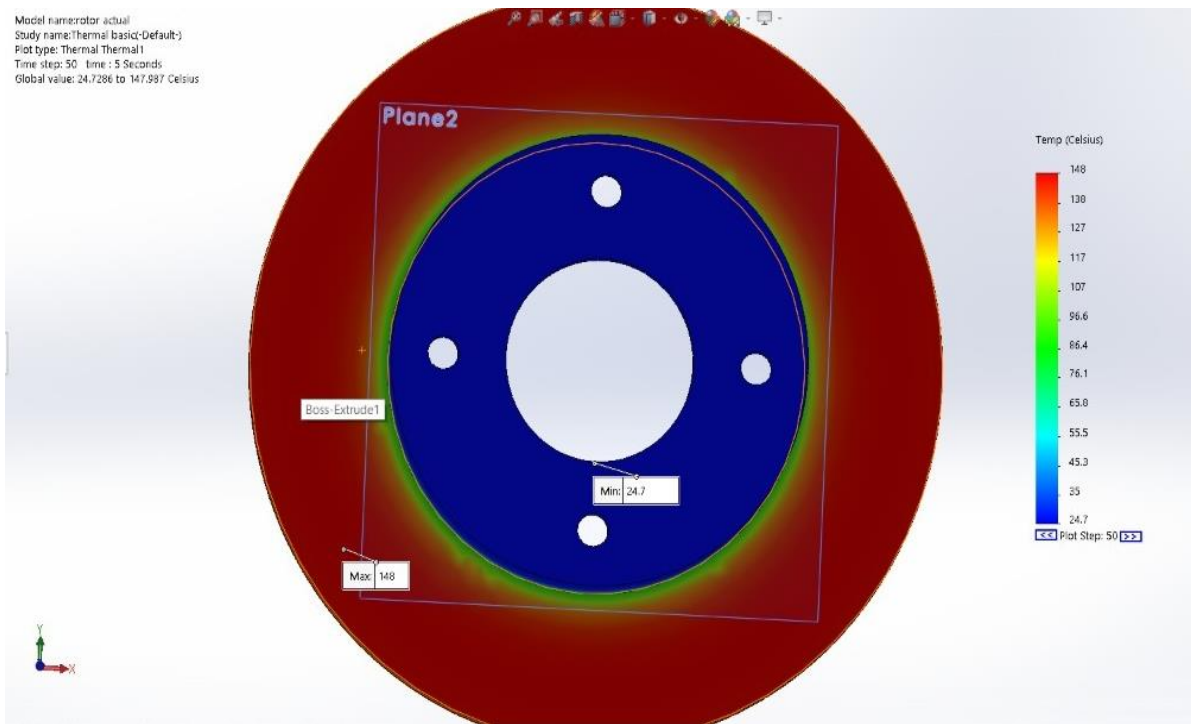


Fig 6.25 Temperature distribution for Ductile iron rotor

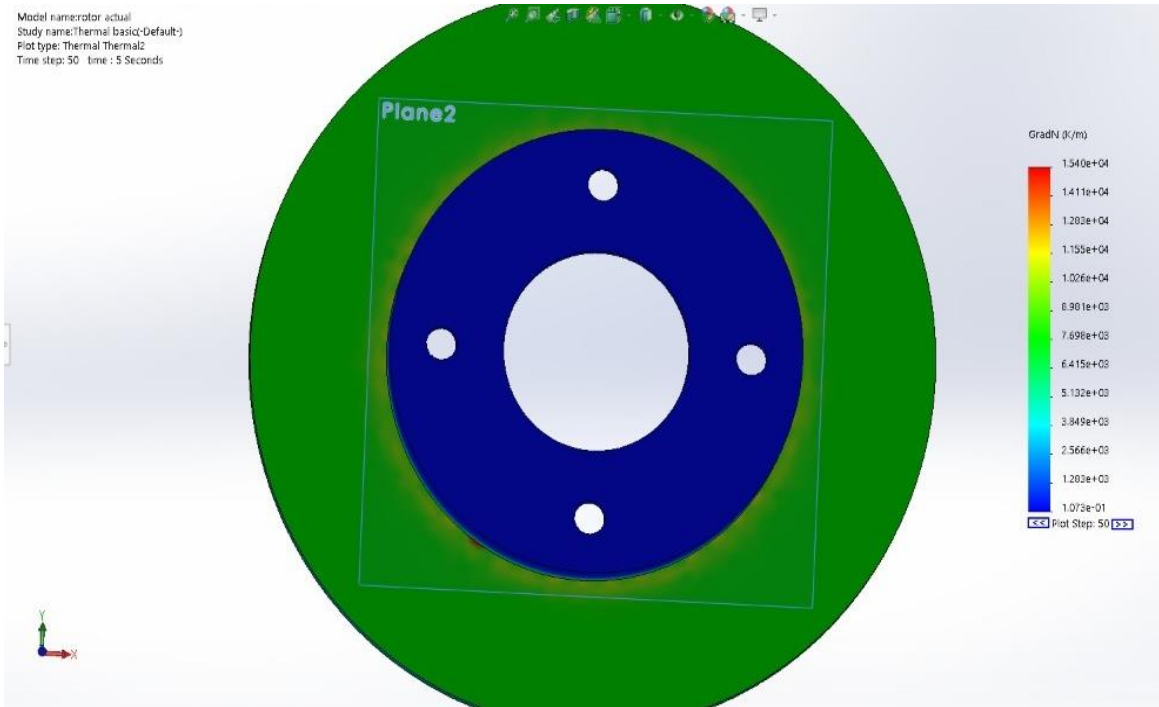


Fig 6.26 Resultant Temperature gradient for Ductile iron rotor

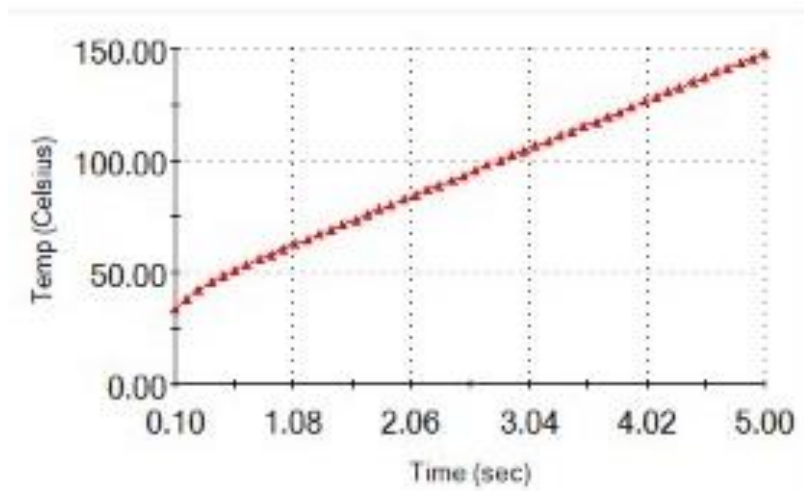


Fig 6.27 Temperature vs time for Ductile iron disc brake

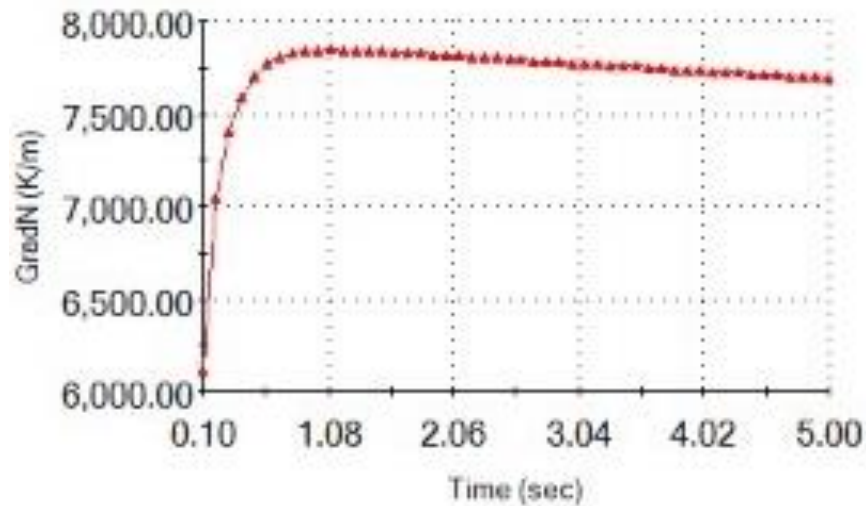


Fig 6.28 Temperature Gradient vs time for Ductile iron disc brake

Table 6.1 Temperature Distribution table.

Materials	Maximum temperature(°C)	Minimum temperature(°C)
Grey cast iron	266	24.4
Ductile iron	147	24.7
Grey cast iron with cu liner	143	23.6
Grey cast iron with steel liner	143	22.6
Grey cast iron with Mg liner	143	22.6
Grey cast iron with Si liner	142	19.8
Grey cast iron with Brass liner	143	23.6

7. Conclusion

On the basis of the current work, it is concluded that the disc with different material liners which dissipates the heat as grey cast iron. The cast iron has the maximum temperature produced is about 266°C without copper liner. The cast iron has the maximum temperature produced is about 143°C with the presence of copper liner. So from above we can conclude that copper liner can be used in brake disc which will give moderate cooling at low temperature as compare to grey cast iron. So it can be used in racing cars where high temperature will produced.

8. REFERENCE

- [1] KENNEDY, F. E., COLIN, F. FLOQUET, A. AND GLOVSKY, R. Improved Techniques for Finite Element Analysis of Sliding Surface Temperatures. Westbury House page 138- 150, (1984).
- [2] A. R. Abu Bakar and H. Ouyang, Wear prediction of friction material and brake squeal using the finite element method. *Wear*, Vol.264 No.11-12, pp.1069-1076,2008.
- [3] Muhamad Ibrahim Mahmud, Kannan M. Munisamy, —Experimental analysis of ventilated brake disc with different blade configurationll Department of mechanical Engineering,
Vol. 1, PP 1-9, 2011
- [4] P.F.Gotowicki, V.Nigrelli and G.V.Mariotti, Numerical and experimental analysis of a pegs-wing ventilated disk brake rotor, with pads and cylinders, In: 10th EAEC Eur.Automot. Cong – Paper EAEC05YUAS04– P 5, June, 2005.
- [5] Hudson, M., Ruhl, R., Ventilated brake rotor air flow investigation, SAE Technical Paper 971033, 1997.
- [6] Wallis, L., Leonardi, E., Milton, B., Air flow and heat transfer in ventilated disc brake rotors with diamond and tear-drop pillars, *Proceedings of International Symposium on Advances in Computational Heat Transfer*, Australia, 2002, pp. 643–655.
- [7] Lee, K. J., Barber, J. R., An experimental investigation of frictionally-excited thermoelastic instability in automotive disk brakes under a drag brake application, *Journal of Tribology* 116 (1994) 409–414.
- [8] Lee, K., Barber, J. R., Frictionally excited thermoelastic instability in automotive disk brakes, *ASME Journal of Tribology* 115 (1993) 607–614.
- [9] Voldřich, J., Frictionally excited thermoelastic instability in disc brakes-transient problem in the full contact regime, *International Journal of Mechanical Sciences* 49 (2007) 129– 137.
- [10] Zagrodzki, P., Thermoelastic instability in friction clutches and brakes-transient modal analysis revealing mechanisms of excitation of unstable modes, *International Journal of Solids and Structures* 46 (2009) 2 463–2 476.
- [11] Zhu, Z. C., Peng, U. X., Shi, Z. Y., Chen, G. A., Three-dimensional transient temperature field of brake shoe during hoist's emergency braking, *Applied Thermal Engineering* 29 (2009) 932–937.
- [12] Komanduri, R., Hou, Z. B., Analysis of heat partition and temperature distribution in sliding systems, *Wear* 251 (1–12) (2001) 925–938.

- [13] Öztürk, B., Arslan, F., Öztürk, S., Effects of different kinds of fibers on mechanical and tribological properties of brake friction materials, *Tribology Transactions* 56 (4) (2013) 536–545.
- [14] Abu Bakar, A. R., Ouyang, H., Wear prediction of friction material and brake squeal using the finite element method, *Wear* 264 (11–12) (2008) 1 069–1 076.
- [15] Abdo, J., Experimental technique to study tangential to normal contact load ratio, *Tribology Transactions* 48 (2005) 389–403.
- [16] Gao, C. H., Lin, X. Z., Transient temperature field analysis of a brake in a non-axisymmetric three-dimensional model, *Journal of Materials Processing Technology* 129 (2002) 513–517.
- [17] Voldřich, J., Morávková, S., Student, J., Transient temperature field in intermittent sliding contact at temperature dependent coefficient of friction, *Proceedings of Computational Mechanics 2006, Nečtiny, 2006*, pp. 697–704.
- [18] Nouby, M., Abdo, J., Mathivanan, D., Srinivasan, K., Evaluation of disc brake materials for squeal reduction, *Tribology Transactions* 54 (4) (2011) 644–656.