# Design and Analysis of Automobile Disc Rotor Using Different Materials

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**Abstract:**
These day technologies go beyond us. For automotive field, the technology of engine develops very fast. Although the engineer gives priority for safety measure, but most consumers still have inadequate knowledge in safety system. Instead of having air bags, good suspension systems, good handling and safe cornering, there is one most critical system in the vehicle which is brake systems.Braking is a process which converts a vehicle's kinetic energy into mechanical energy which must be dissipated in the form of heat. During the braking phase, the frictional heat generated at the interface of the disc and pads can lead to high temperatures. The frictional heat generated on the rotor surface can influence excessive temperature rise which, in turn, leads to undesirable effects such as thermal elastic instability (TEI), premature wear, brake fluid vaporization (BFV) and thermally excited vibrations (TEV). In this project, we have conducted a study on solid,drilled and ventilated type disc brake rotor of normal passenger vehicle. The project is aimed at evaluating the performance of disc brake rotor under braking conditions and there by assist in disc rotor design and analysis.

**Keywords:** CATIA, ANSYS, VONMISSES STRESS,HEAT FLUX.

**PRINCIPLE**

## 1. *INTRODUCTION*

Brakes are most important safety parts in the vehicles. Generally all of the vehicles have their own safety devices to stop their car. Brakes function to slow and stop the rotation of the wheel. To stop the wheel, braking pads are forced mechanically against the rotor or disc on both surfaces. They are compulsory for all of the modern vehicles and the safe operation of vehicles. In short, brakes transform the kinetic energy of the car into heat energy, thus slowing its speed.

**BRAKING REQUIREMENTS**

**1)** The brakes must be strong enough to stop the vehicle within a minimum distance in an emergency. But this should also be consistent with safety. The driver must have proper control over the vehicle during emergency braking and the vehicle must not skid.

**2)** The brakes must have good anti-fade characteristics i.e. their effectiveness should not decrease with constant prolonged application e.g., while descending hills. This requirement demands that the cooling of the brakes should be very efficient.

**BRAKE EFFICIENCY AND STOPPING DISTANCE**

The maximum retarding force applied by the brake at the wheels, F, depends upon the coefficient of friction between the road and the tyre surface μ, and the component of the weight of the vehicle on the wheel, W, i.e.,

$$F = \mu W$$

**CLASSIFICATION OF BRAKES**

**1) Purpose:**

- Primary brakes
- Secondary brakes

**2) Construction:**

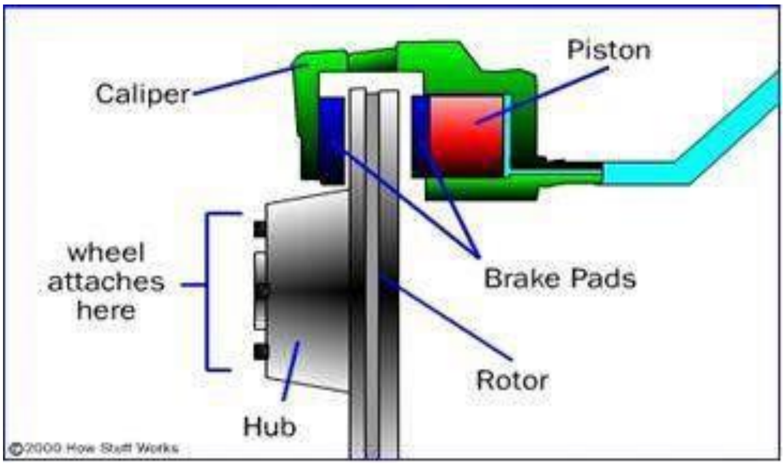
- Drum brakes
- Disc brakes

**3) Method of Actuation:**

- Mechanical brakes
- Hydraulic brakes
- Electric brakes
- Vacuum brakes
- Air brakes
- By-wire brakes

**4) Extra braking effort:**

- Power assisted brakes
- Power operated brakes




Parts of a disc brake

Table 1.2 Material properties

| PROPERTIES | Aluminium Metal Matrix | Titanium Alloy | Structural Steel | Gray Cast Iron | Carbon Ceramic |
|---|---|---|---|---|---|
| Density , $Kg/m^3$ | 2712 | 4620 | 7850 | 7200 | 1750 |
| Thermal conductivity , w/m-K | 250 | 20 | 60 | 54 | 1.45 |
| Young's Modulus , $N/m^2$ | $69\times10^9$ | $9.6\times10^{10}$ | $2\times10^{11}$ | $1\times10^{11}$ | $1.95\times10^{11}$ |
| Poisson's Ratio | 0.33 | 0.36 | 0.3 | 0.28 | 0.31 |
| Specific Heat , J/Kg-K | 910 | 520 | 490 | 586 | 850 |
| Coefficient of Linear Expansion , /K | $23\times10^{-6}$ | $9.6\times10^{-6}$ | $11.7\times10^{-6}$ | $9.9\times10^{-6}$ | $2\times10^{-6}$ |

## LITERATURE REVIEW

**Blot [2]** defined several numerical procedures for the temperature analysis of brake discs and revealed that the FE technique was the fastest and most accurate for the investigation of brake disc performance. Furthermore, the time and cost of prototype manufacture and test could be significantly reduced.

**Sheridan et al. [3]** reviewed the techniques for modelling the thermal response of brake discs ranging from simple to complex three dimensional analyses including the methods to calculate the thermal boundary conditions. They suggested that more than 90% of all heat dissipated to ambient was transferred by convection for most braking conditions. Furthermore, the accuracy of thermal brake disc models was dependent on how the thermal boundary conditions were determined. As well as specifying the energy input and output accurately, the material properties (e.g. thermal conductivity, specific heat, etc.) had a great influence on the temperature response.

**Yano and Murata [4]** performed experimental work to determine the amount of heat now from the frictional interface into the rotor by conduction. The volume or quantity of heat transferring to the pads, the rotor and the ambient air was obtained from the measured temperature gradients and heat transfer coefficients. According to their experiments, the heat conduction from the rubbing surfaces to the rotor was approximately 72% of the heat generated.

ketching of solid,ventilated and drilled:

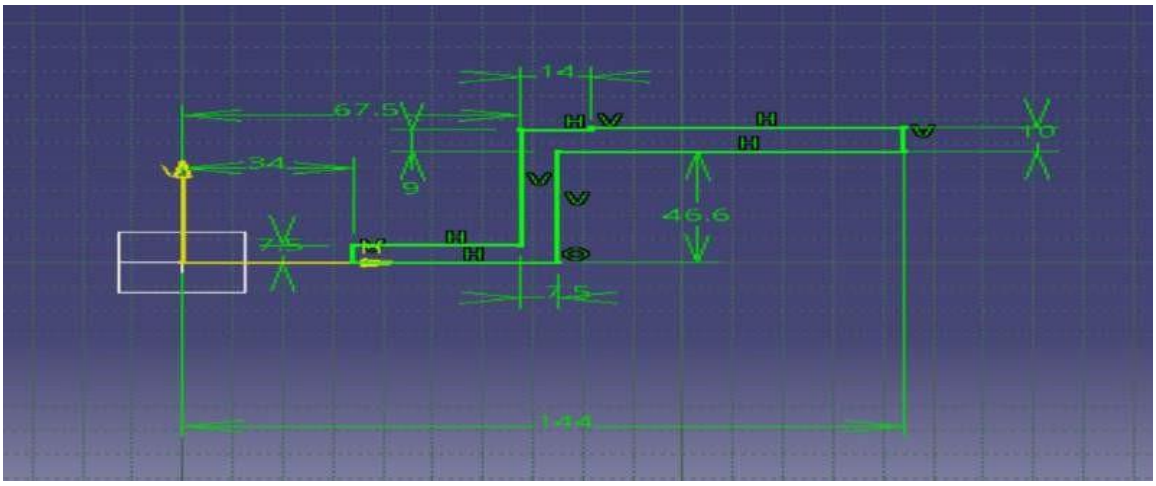



Fig. 3.1 Sketch of Solid type disc brake

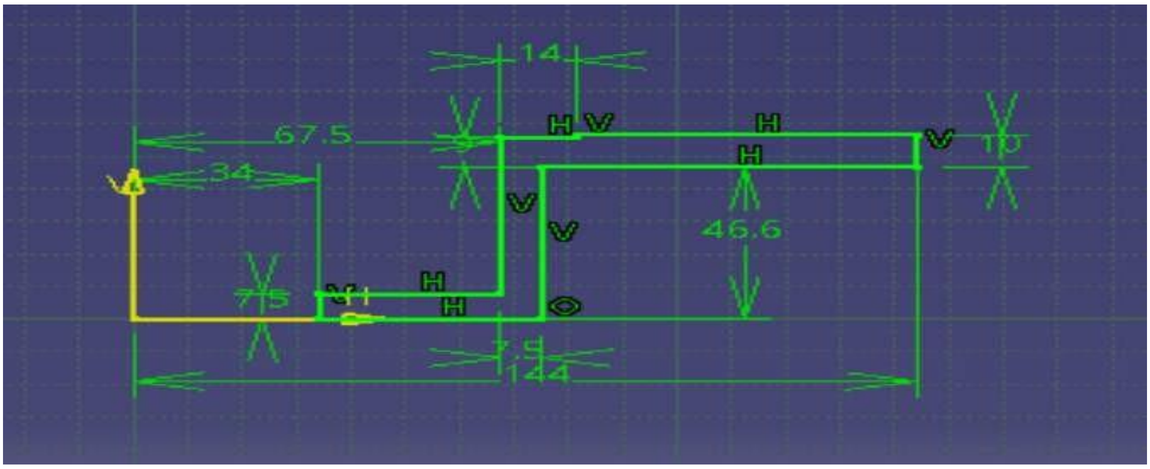



Fig. 3.2 Sketch of Ventilated type disc brake

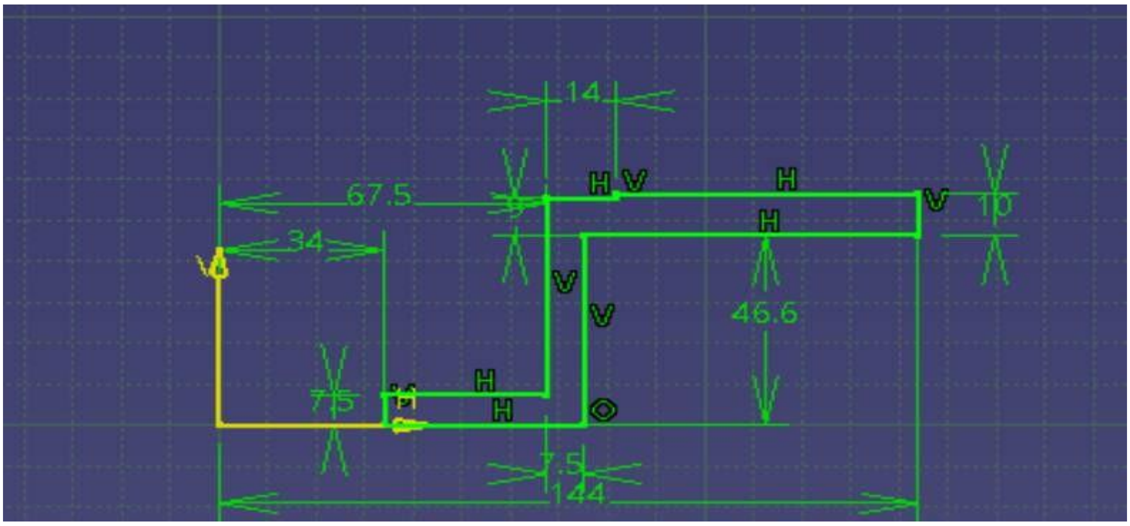



Fig. 3.3 Sketch of Drilled type disc brake

**Modelling and Meshing of Solid,Ventilated and Drilled disc brake:**

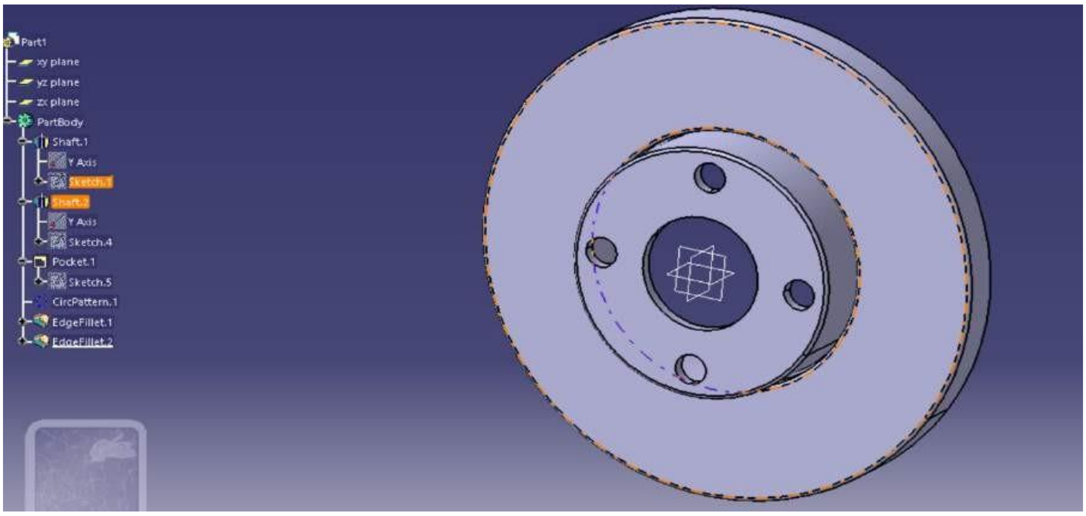



Fig. 3.4 Solid model of Solid disc brake

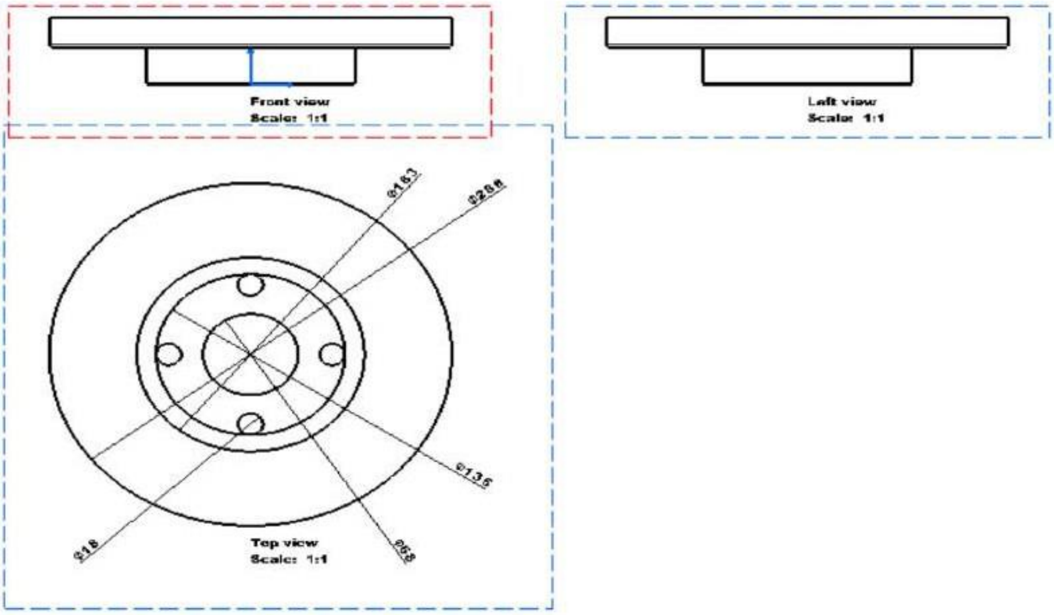



Fig. 3.5 Drafting of Solid disc brake

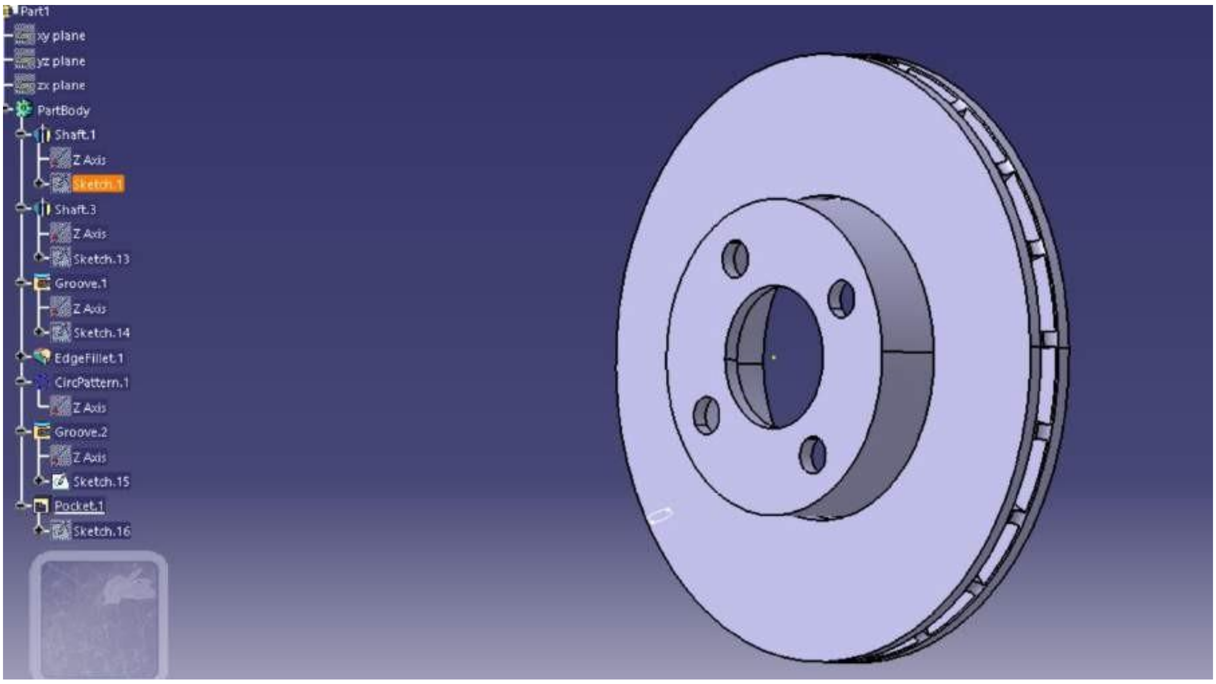



Fig. 3.6 Solid model of Ventilated disc brake

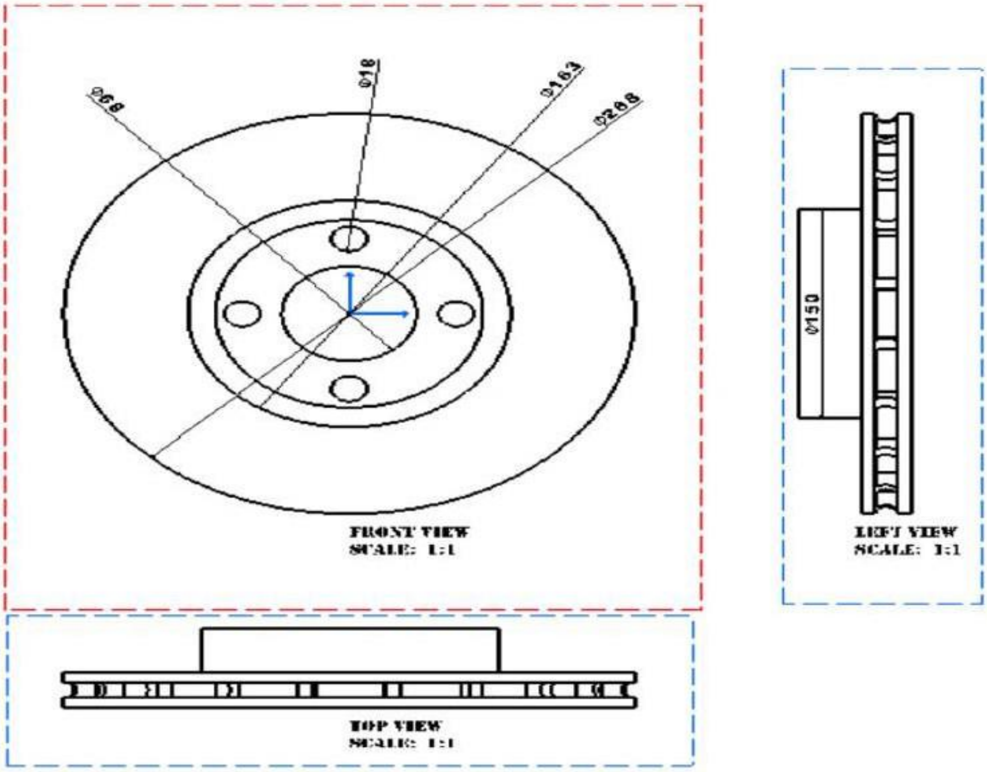



Fig. 3.7 Drafting of Ventilated disc brake

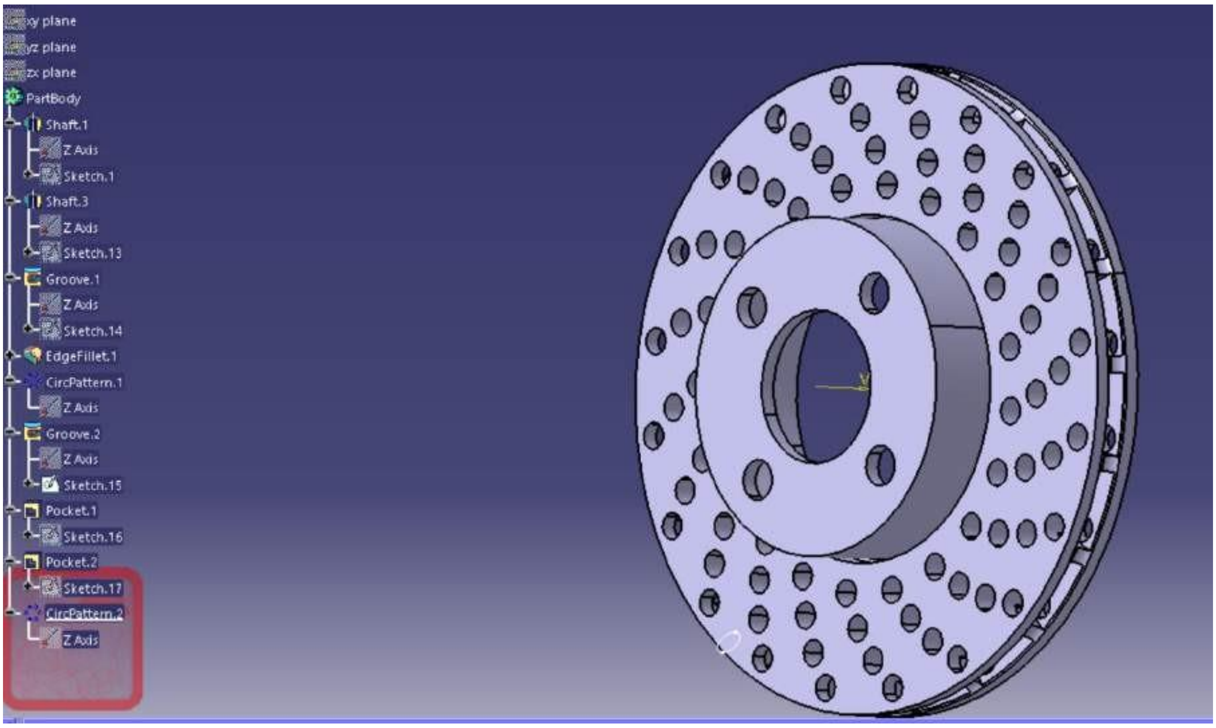



Fig. 3.8 Solid model of Drilled disc brake

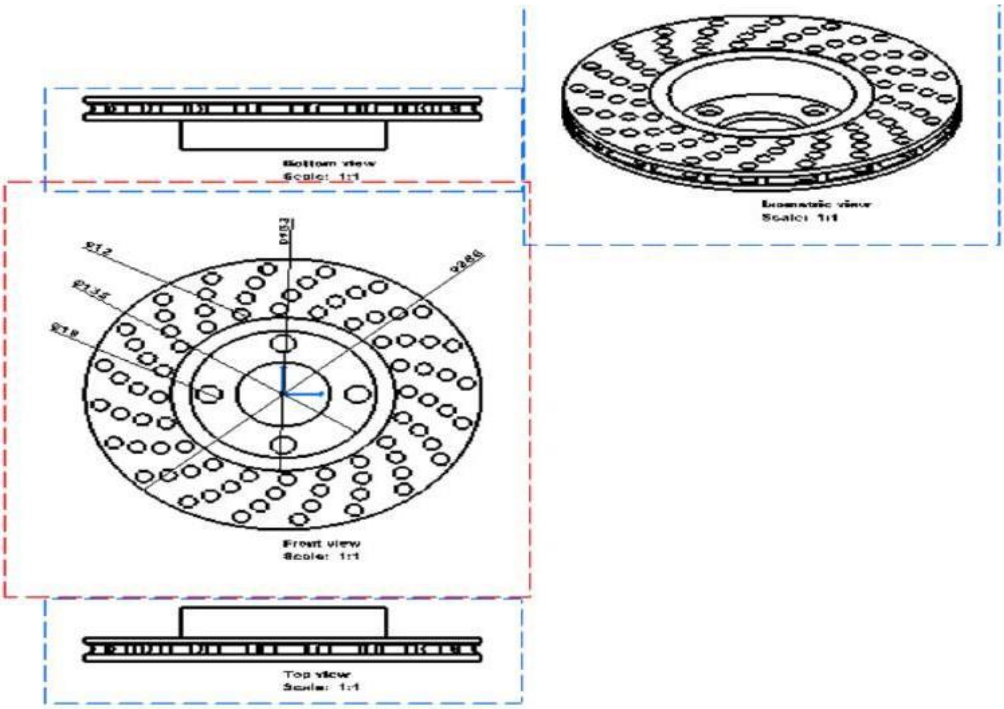



Fig. 3.9 Drafting of Drilled disc brake

**ANSYS:**

ANSYS is a general-purpose finite element modelling package for numerically solving a wide variety of mechanical problems. ANSYS simulation software enables organisations to confidently predict how their products will operate in the real world. It expands the use of physics. It gains access to any form of engineering field someone may account in. The ANSYS program has many finite element analysis capabilities, ranging from a simple, linear, static analysis to a complex, nonlinear, transient dynamic analysis.

A typical ANSYS analysis has three distinct steps:

1. Build the model.
2. Apply loads and obtain the solution.
3. Review the results.

(1) <u>Building a Model</u>

Building a finite element model requires more of an ANSYS user's time than any other part of the analysis. First, you specify a job name and analysis title. Then, you use the PREP7 pre- processor to define the element types, element real constants, material properties, and the model geometry.

(2) <u>Apply loads and obtain the solution</u>

In this step, you use the SOLUTION processor to define the analysis type and analysis options, apply loads, specify load step options, and initiate the finite element solution. You also can apply loads using the PREP7 pre-processor.

(3) <u>Review the results</u>

Once the solution has been calculated, you can use the ANSYS postprocessors to review the results. Two postprocessors are available: POST1 and POST26.

## LOADING OVERVIEW

The main goal of a finite element analysis is to examine how a structure or component responds to certain loading conditions. Specifying the proper loading conditions is, therefore, a key step in the analysis. The loads can be applied on the model in a variety of ways in the ANSYS program. Also, with the help of load step options, one can control how the loads are actually used during solution.

## SOLUTION

In the solution phase of the analysis, the computer takes over and solves the simultaneous equations that the finite element method generates. The results of the solution are:

- nodal degree-of-freedom values, which form the primary solution
- derived values, which form the element solution

## STRUCTURAL ANALYSIS

Structural analysis is probably the most common application of the finite element method. The term *structural* (or *structure)* implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

**TYPES:**

The seven types of structural analyses available in the ANSYS family of products are explained below. The primary unknowns (nodal degrees of freedom) calculated in a structural analysis are *displacements*. Other quantities, such as strains, stresses, and reaction forces, are then derived from the nodal displacements.

Structural analyses are available in the ANSYS/Multi physics, ANSYS/Mechanical, ANSYS/Structural, and ANSYS/Linear Plus programs only.
One can perform the following types of structural analyses:

***Static Analysis*** - Used to determine displacements, stresses, etc. under static loading conditions. It comprises of both linear and non linear static analysis. Non-linearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.

***Modal Analysis*** - Used to calculate the natural frequencies and mode shapes of a structure. Different mode extraction methods are available.

***Harmonic Analysis*** - Used to determine the response of a structure to harmonically time-varying loads.

***Transient Dynamic Analysis*** - Used to determine the response of a structure to arbitrarily time- varying loads. All non linearities mentioned under Static Analysis above are allowed.
***Spectrum Analysis*** - An extension of the modal analysis, used to calculate stresses and strains due to a response spectrum or a PSD input (random vibrations).

***Buckling Analysis*** - Used to calculate the buckling loads and determine the buckling mode shape. Both linear (eigen value) buckling and nonlinear buckling analyses are possible.

***Explicit Dynamics Analysis*** - ANSYS provides an interface to the LS-DYNA explicit finite element program and is used to calculate fast solutions for large deformation dynamics and complex contact problems.

In addition to the above analysis types, several special-purpose features are available:

- Fracture mechanics
- Composites
- Fatigue
- p-Method

**THERMAL ANALYSIS**

A *thermal analysis* calculates the temperature distribution and related thermal quantities in a system or component. Typical thermal quantities of interest are:

- The temperature distributions
- The amount of heat lost or gained
- Thermal gradients
- Thermal fluxes.

Thermal simulations play an important role in the design of many engineering applications, including internal combustion engines, turbines, heat exchangers, piping systems, and electronic components. In many cases, engineers follow a thermal analysis with a stress analysis to calculate *thermal stresses* (that is, stresses caused by thermal expansions or contractions).

Only the ANSYS/Multi physics, ANSYS/Mechanical, ANSYS/Thermal, and ANSYS/FLOTRAN programs support thermal analysis.
The basis for thermal analysis in ANSYS is a heat balance equation obtained from the principle of conservation of energy. The finite element solution one performs via ANSYS calculates nodal temperatures and then uses the nodal temperatures to obtain other thermal quantities.
The ANSYS program handles all three primary modes of heat transfer: conduction, convection, and radiation.
**TYPES:**

ANSYS supports two types of thermal analysis:

(1) *A* **steady-state thermal analysis** determines the temperature distribution and other thermal quantities under steady-state loading conditions. A steady-state loading condition is a situation where heat storage effects varying over a period of time can be ignored.
(2) *A* **transient thermal analysis** determines the temperature distribution and other thermal quantities under conditions that vary over a period of time.

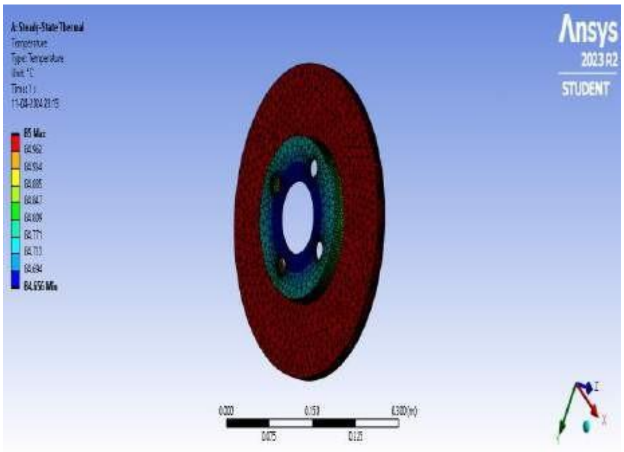
***RESULTS***

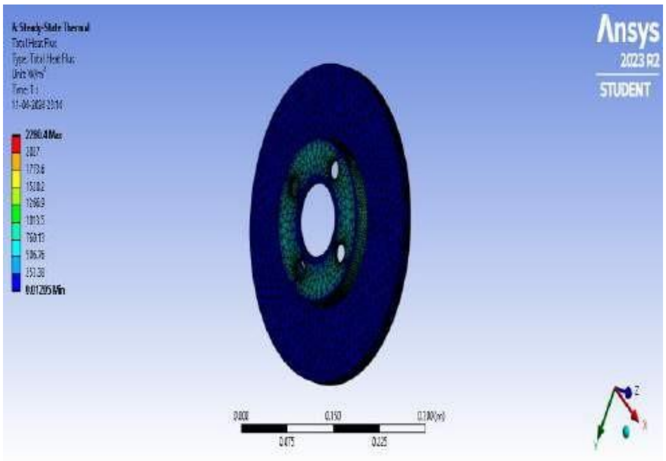
The results shown below are of Ventilated,Drilled and Solid type disc brake made of Aluminium metal matrix, Gray Cast Iron, Titanium alloy,Structural steel,Carbon Ceramic. These results are obtained after applying the thermal and structural boundary conditions and performing the Coupled Thermal-Structural Analysis. The minimum and maximum values of Temperature, Total Heat Flux, Total Deformation, Equivalent (von-Mises) Stress are interpreted in the form of colours such as blue being the minimum, green being the intermediate temperature and red being the maximum.

## THERMAL ANALYSIS

### (1) Ventilated disc brake

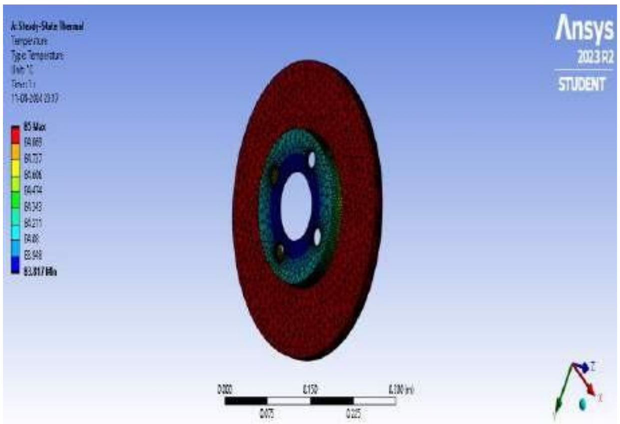
#### (a) Aluminium metal matrix

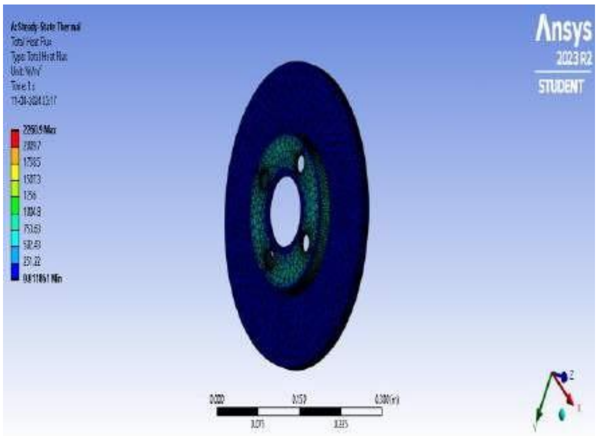





The above figures display the Temperature and Total heat flux of Ventilated disc brake made of Aluminium metal matrix. As it is evident from the figures, the minimum temperature and the maximum total heat flux are represented by Blue & Red and the values being, 84.42°C and 2280.4 w/m$^2$ respectively.

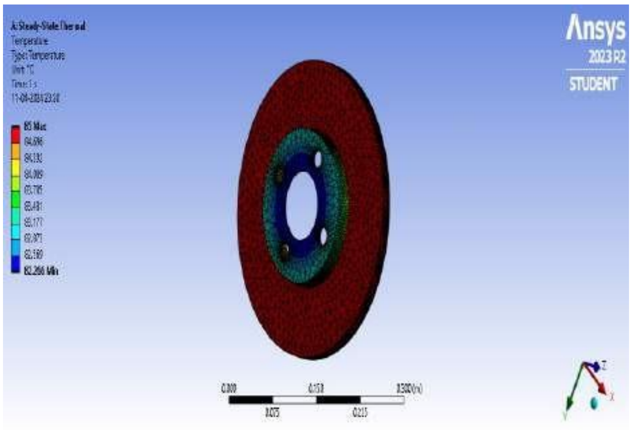
#### (b) Gray Cast Iron

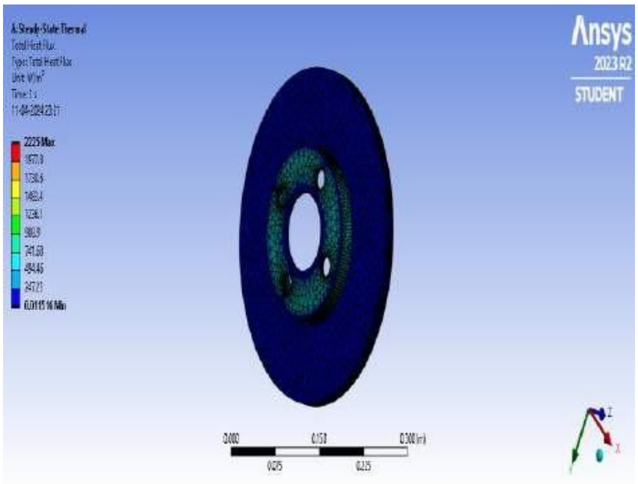





The above figures display the Temperature and Total heat flux of Ventilated disc brake made of Gray Cast Iron. As it is evident from the figures, the minimum temperature and the maximum total heat flux are represented by Blue & Red colour and the values being, 83.3°C and 2260.9 w/m$^2$
respectively.

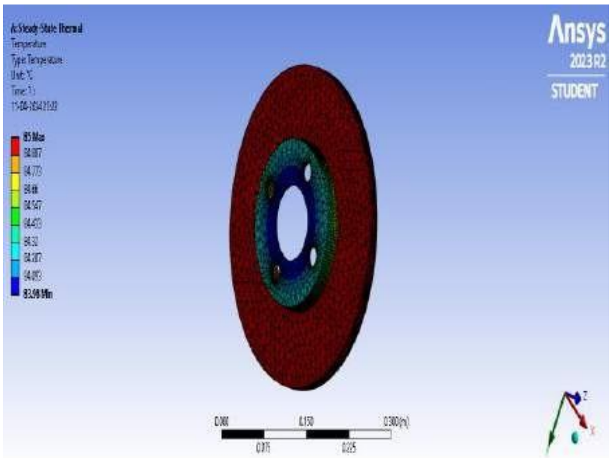
**(c) Titanium Alloy**

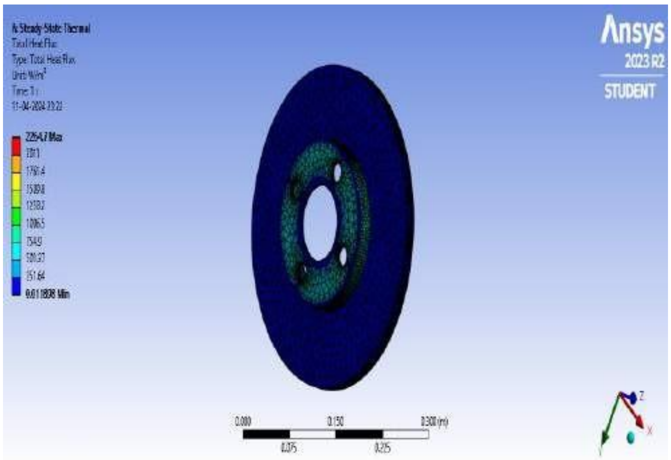



The above figures display the Temperature and Total heat flux of Ventilated disc brake made of Titanim alloy. As it is evident from the figures, the minimum temperature and the maximum total heat flux are represented by Blue & Red and the values being, 82.66 °C and 2225 w/m$^2$ respectively.

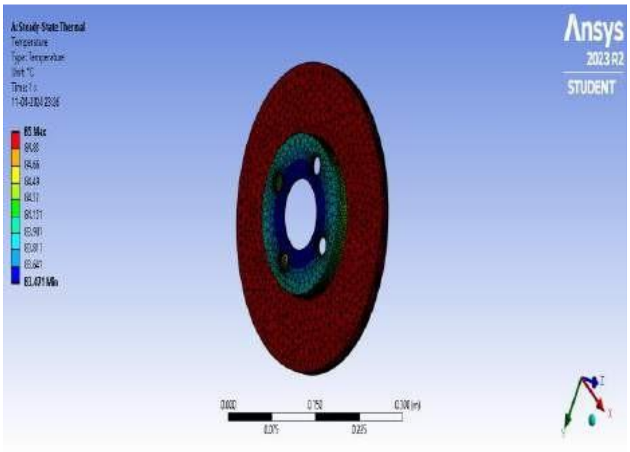
**(d) Stuctural Steel**

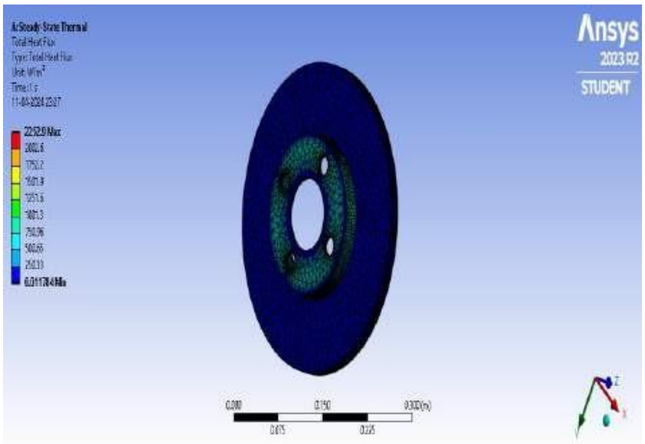



The above figures display the Temperature and Total heat flux of Ventilated disc brake made of structural steel. As it is evident from the figures, the minimum temperature and the maximum total heat flux are represented by BLUE & Red colour and the values being, 83.98 °C and 2264.7 w/m$^2$ respectively.

**(e) Carbon Ceramic**

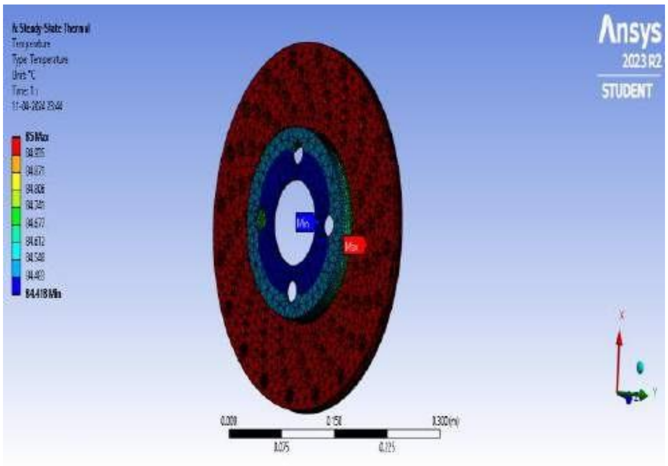


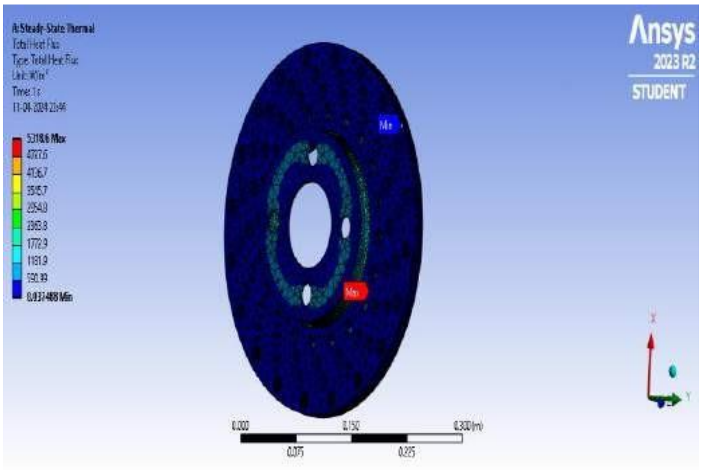




The above figures display the Temperature and Total heat flux of Ventilated disc brake made of Carbon ceramic. As it is evident from the figures, the minimum temperature and the maximum total heat flux are represented by Blue & Red colour and the values being, 83.47°C and 2252.9 w/m$^2$ respectively.

**(2) <u>Drilled disc brake</u>**

**(a) Aluminium metal matrix**




The above figures display the Temperature and Total heat flux of Drilled disc brake made of Aluminium metal matrix. As it is evident from the figures, the minimum temperature and the maximum total heat flux are represented by Blue & Red colour and the values being, 84.41°C and 5318.6 w/m$^2$ respectively.

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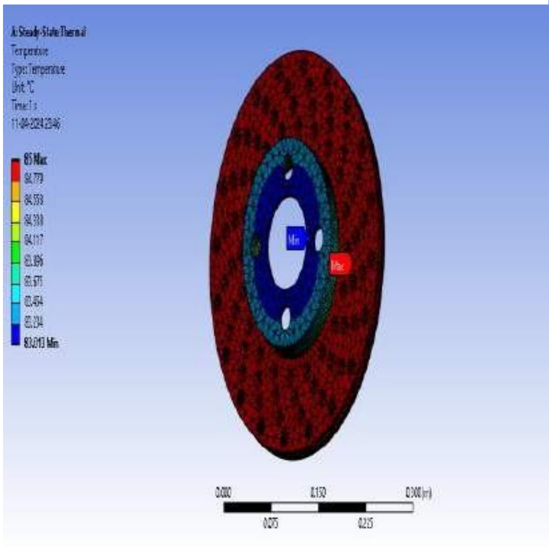
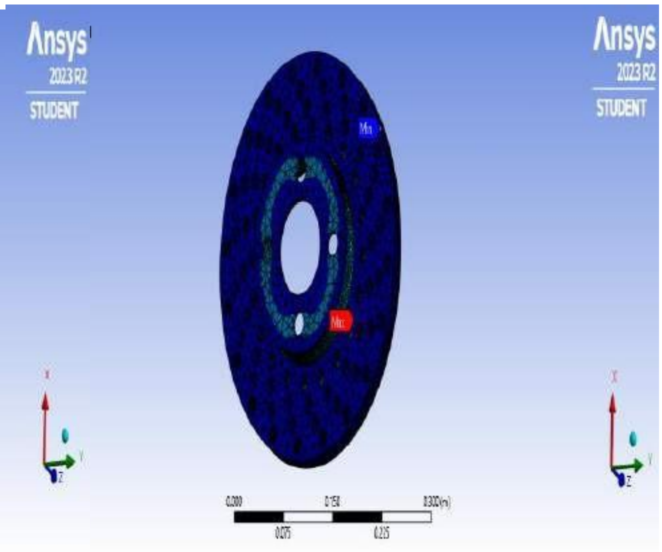
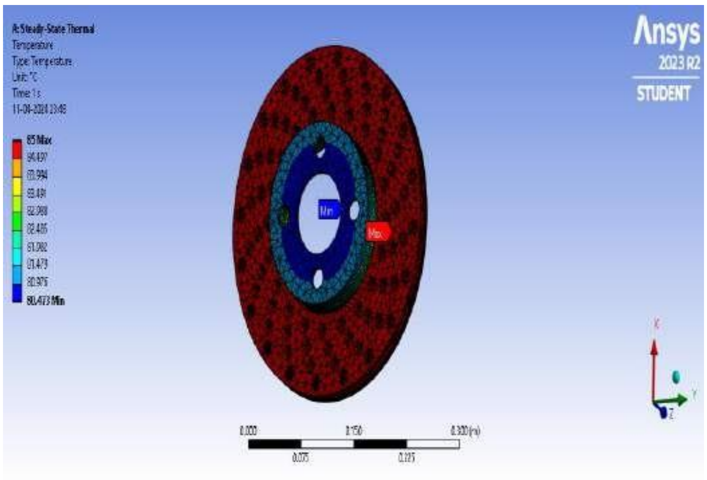
**(b) Gray Cast Iron**

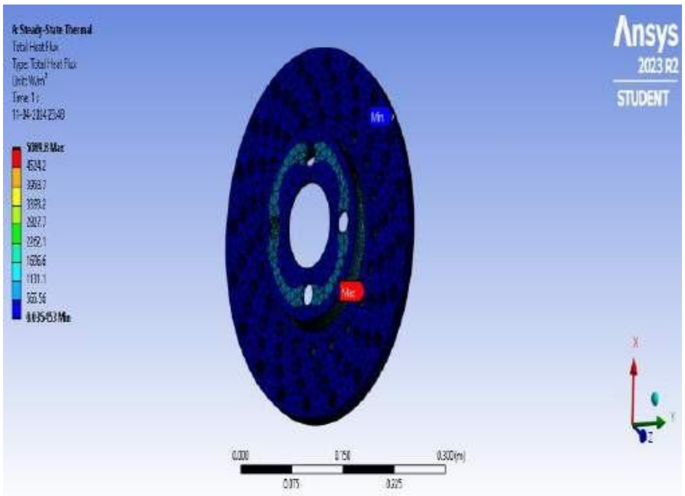





The above figures display the Temperature and Total heat flux of Drilled disc brake made of Gray Cast Iron. As it is evident from the figures, the minimum temperature and the maximum total heat flux are represented by Blue & red colour and the values being, 83.03°C and 5236.9 w/$m^2$ respectively.

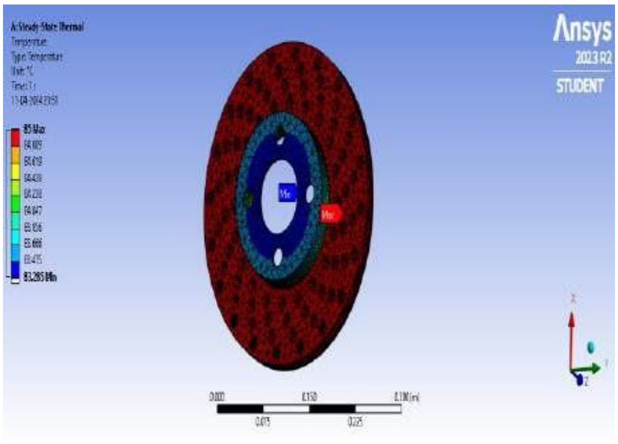
**(c) Titanium Alloy**

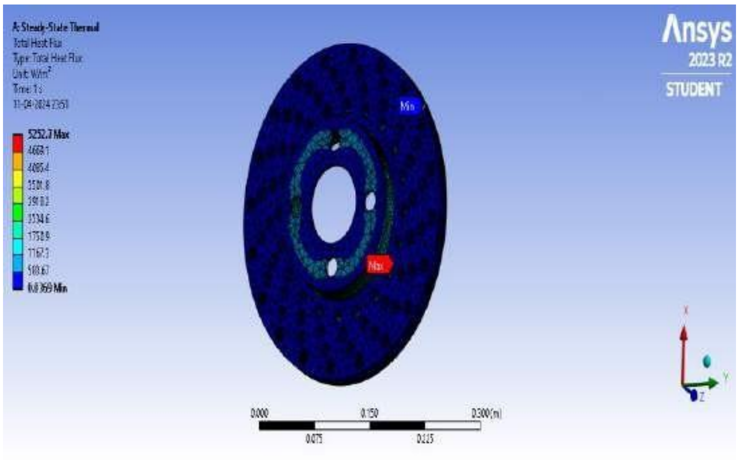





The above figures display the Temperature and Total heat flux of Drilled disc brake made of Titanium alloy. As it is evident from the figures, the minimum temperature and the maximum total heat flux are represented by Blue & red colour and the values being, 80.47°C and 5089.8 w/$m^2$ respectively.

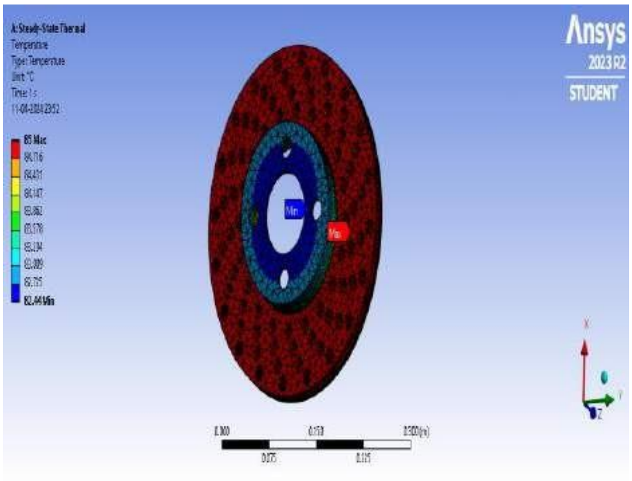
**(d) Stuctural Steel**

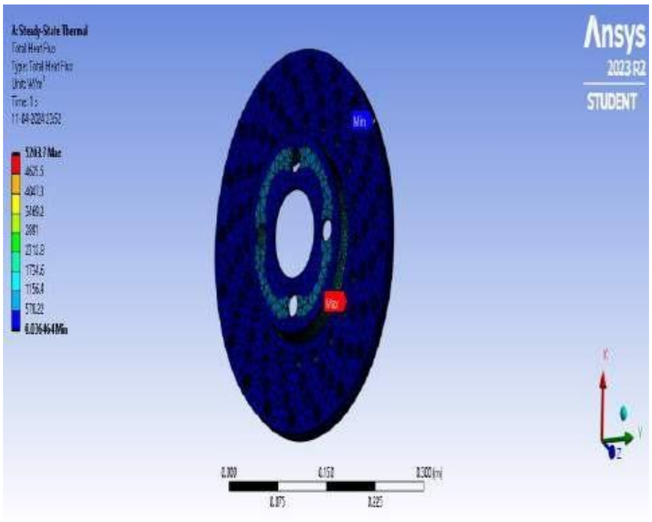



The above figures display the Temperature and Total heat flux of Drilled disc brake made of Structural steel. As it is evident from the figures, the minimum temperature and the maximum total heat flux are represented by Blue & red colour and the values being, 83.2 °C and 5252.7 w/m$^2$ respectively.

**(e) Carbon Ceramic**




The above figures display the Temperature and Total heat flux of Drilled disc brake made of Carbon Ceramic. As it is evident from the figures, the minimum temperature and the maximum total heat flux are represented by Blue & red colour and the values being, 82.44 °C and 5203.7 w/m$^2$ respectively.

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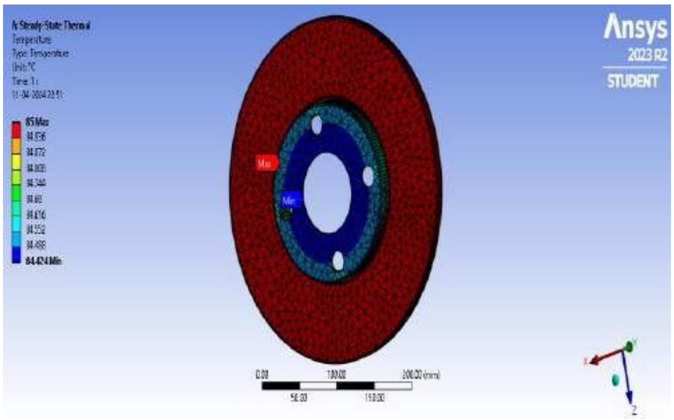
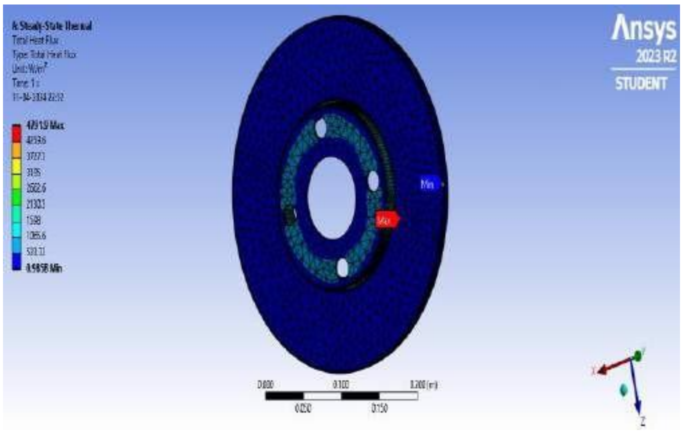
**(3) <u>Solid disc brake</u>**

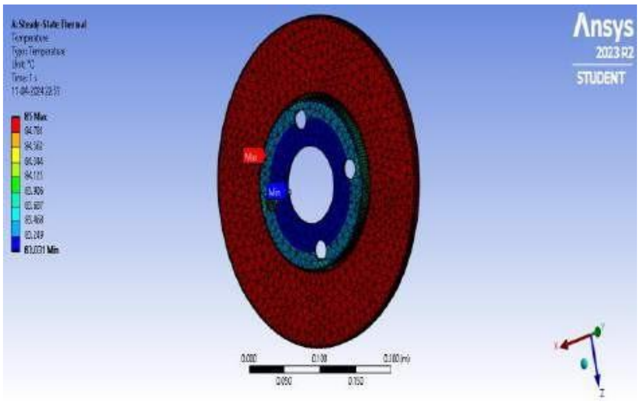
**(a) Aluminium metal matrix**

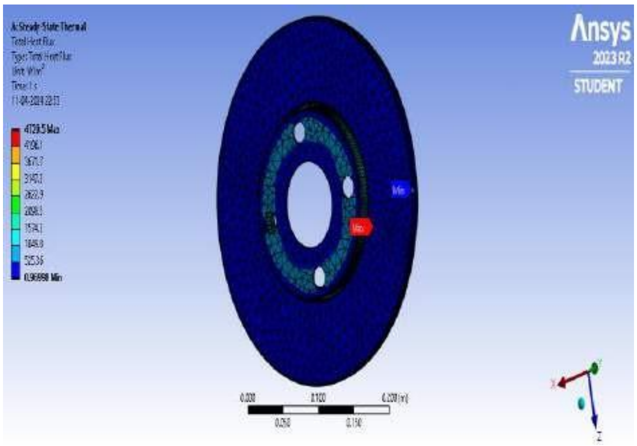



The above figures display the Temperature and Total heat flux of Solid disc brake made of Aluminium. As it is evident from the figures, the minimum temperature and the maximum total heat flux are represented by Blue & red colour and the values being, 84.24°C and 4791 w/m$^2$ respectively.

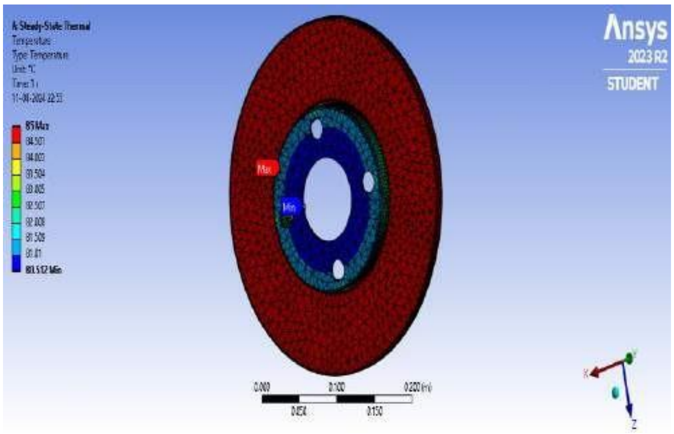
**(b) Gray Cast Iron**

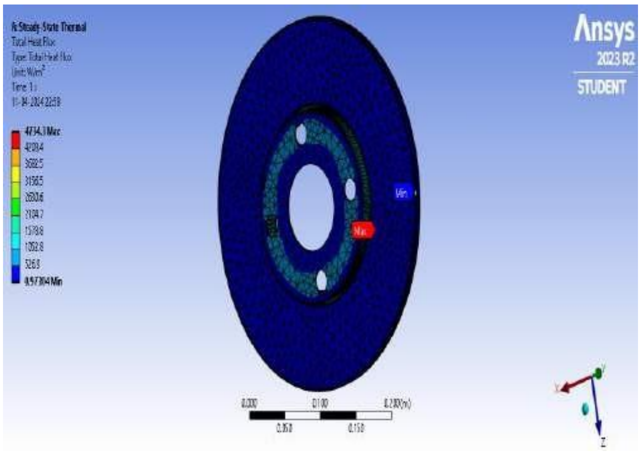



Above figures display the Temperature and Total heat flux of Solid disc brake made of Cast Iron.
As it is evident from the figures, the minimum temperature and the maximum total heat flux are represented by Blue & red colour and the values being, 83.03 °C and 4720 w/m$^2$ respectively.

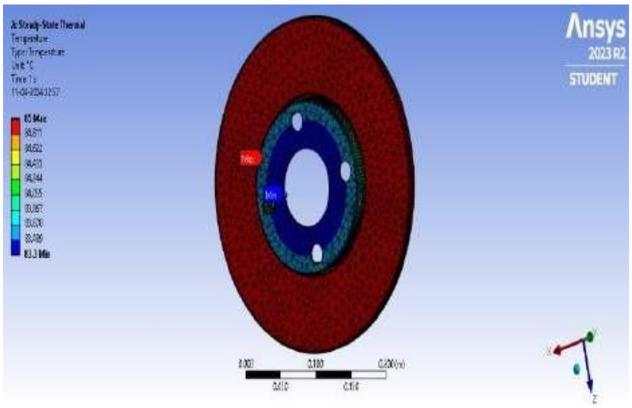
**(c) Titanium Alloy**

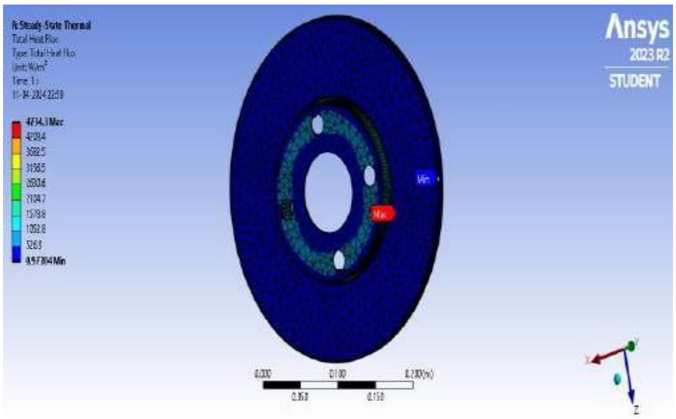



The above figures display the Temperature and Total heat flux of Solid disc brake made of Titanium Alloy. As it is evident from the figures, the minimum temperature and the maximum total heat flux are represented by Blue & red colour and the values being, 80.1°C and 4591.7 w/$m^2$ respectively.

**(d) Stuctural Steel**




The above figures display the Temperature and Total heat flux of Solid disc brake made of Structural alloy. As it is evident from the figures, the minimum temperature and the maximum total heat flux are represented by Blue & red colour and the values being, 83.3°C and 4734.3w/$m^2$ respectively.

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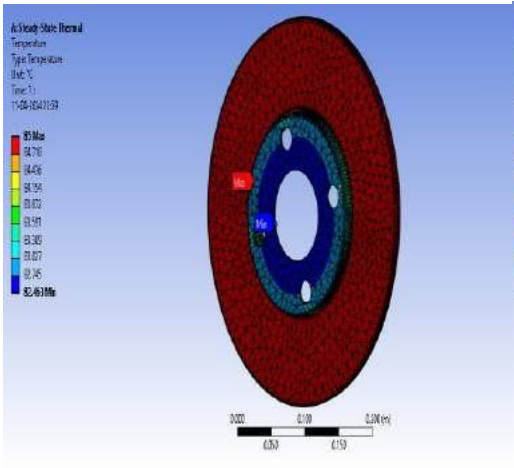
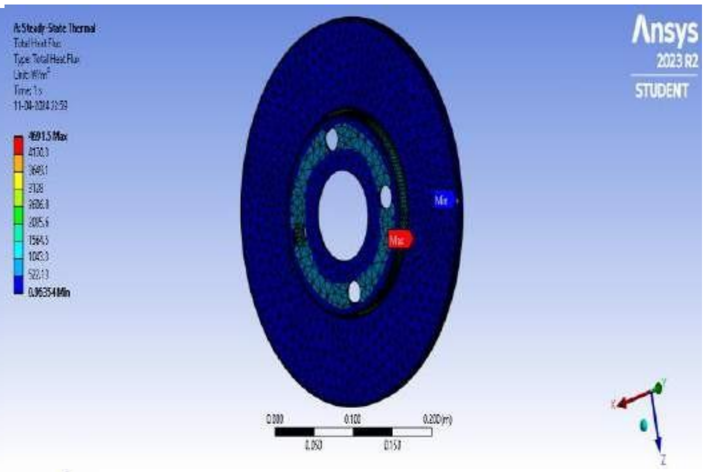
**(e) Carbon Ceramic**

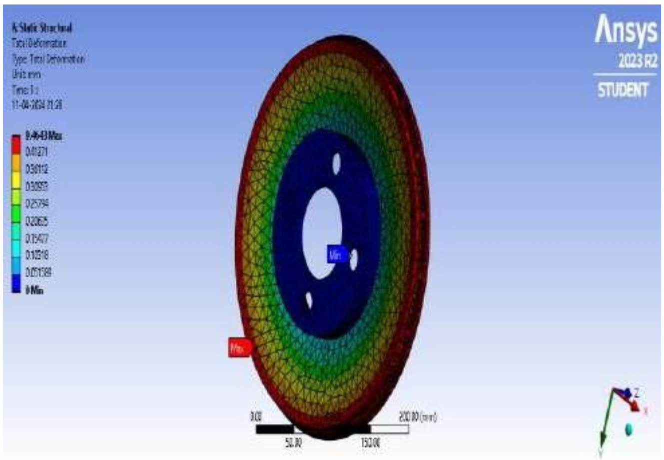



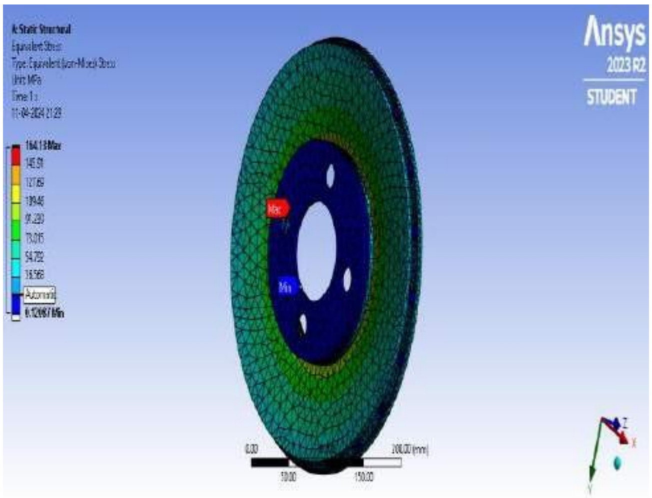

The above figures display the Temperature and Total heat flux of Solid disc brake made of Carbon ceramic. As it is evident from the figures, the minimum temperature and the maximum total heat flux are represented by Blue & red colour and the values being, 82.46°C and 4691.5 w/m$^2$ respectively.

**STRUCTURAL ANALYSIS**

**(1) <u>Ventilated disc brake</u>**

**(a) Aluminium metal matrix**






The above figures display the Total deformation and Equivalent (von-Mises) stress of Ventilated disc brake made of Aluminium. As it is evident from the figures, the maximum total deformation and equivalent (von-Mises) stress are represented by red colour and the values being, 0.464 mm and 164.3 MPa respectively.

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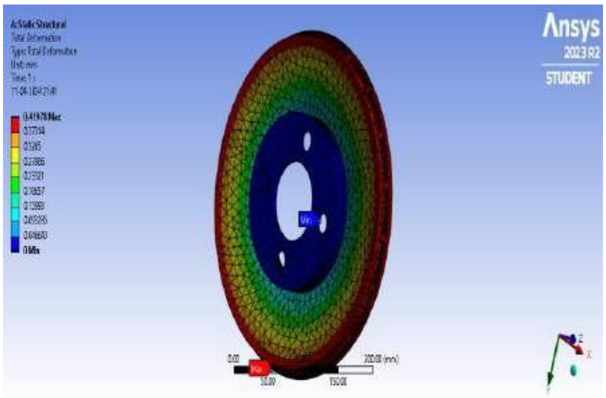
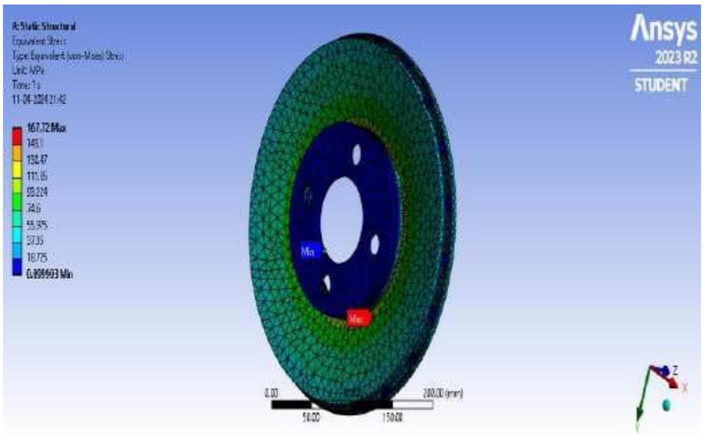
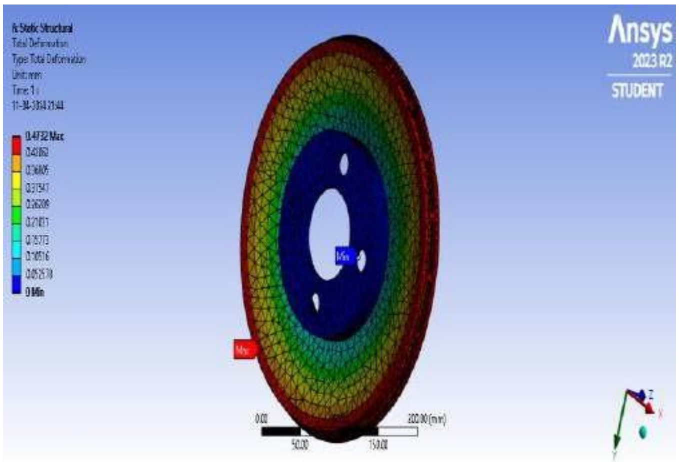
**(b) Gray Cast Iron**

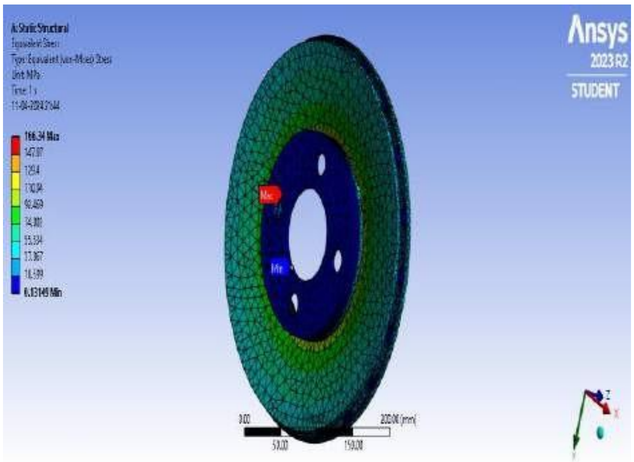



The above figures display the Total deformation and Equivalent (von-Mises) stress of Ventilated disc brake made of Gray Cast Iron. As it is evident from the figures, the maximum total deformation and equivalent (von-Mises) stress are represented by red colour and the values being, 0.419 mm and 167.7 MPa respectively.

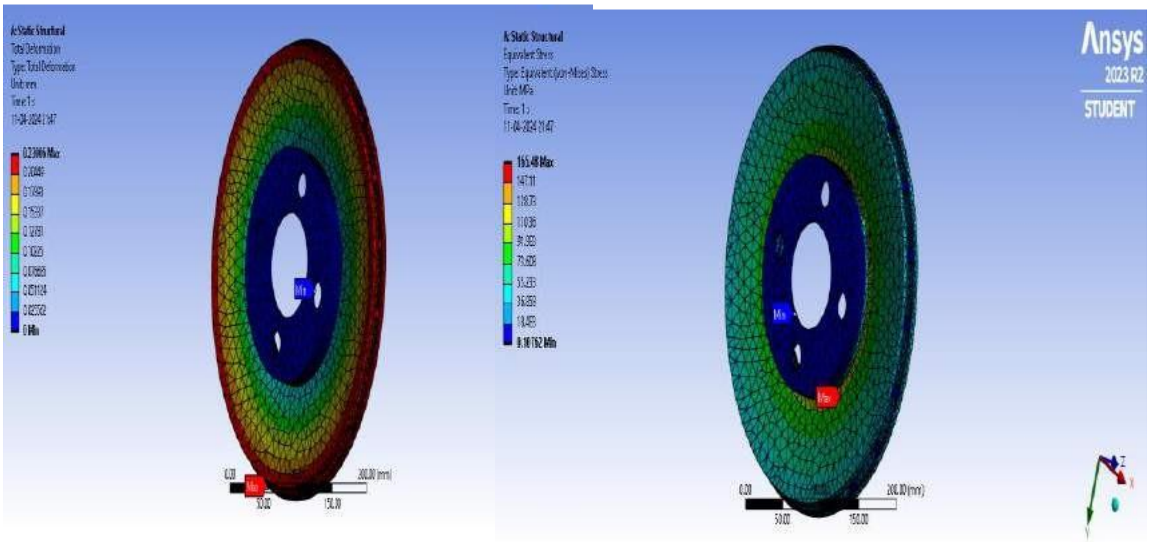
**(c) Titanium Alloy**



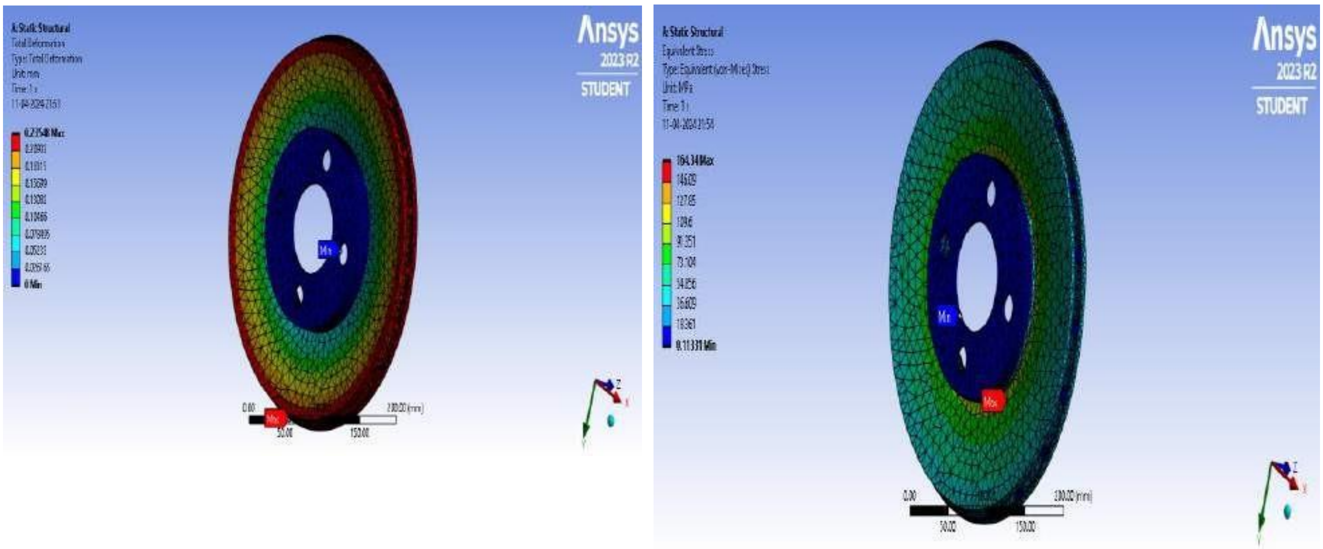

The above figures display the Total deformation and Equivalent (von-Mises) stress of Ventilated disc brake made of Titanium alloy. As it is evident from the figures, the maximum total deformation and equivalent (von-Mises) stress are represented by red colour and the values being, 0.473m and 166.34MPa respectively.

**(d) Structural steel**




The above figures display the Total deformation and Equivalent (von-Mises) stress of Ventilated disc brake made of Structural alloy. As it is evident from the figures, the maximum total deformation and equivalent (von-Mises) stress are represented by red colour and the values being, 0,23mm and 165.48 MPa respectively.

**(e) Carbon ceramic**




The above figures display the Total deformation and Equivalent (von-Mises) stress of Ventilated disc brake made of Carbon Ceramic. As it is evident from the figures, the maximum total deformation and equivalent (von-Mises) stress are represented by red colour and the values being,
0.235 mm and 164.34 MPa respectively.

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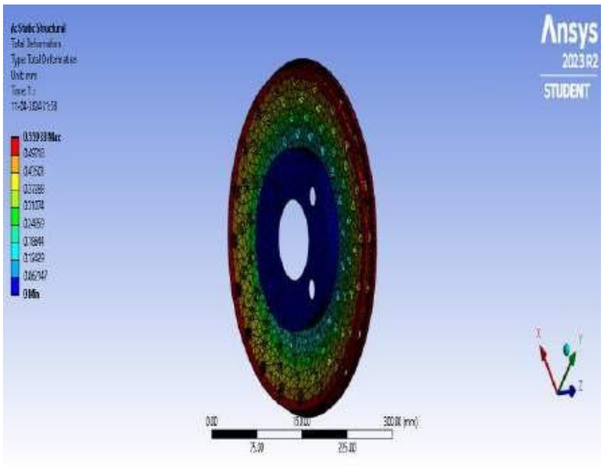
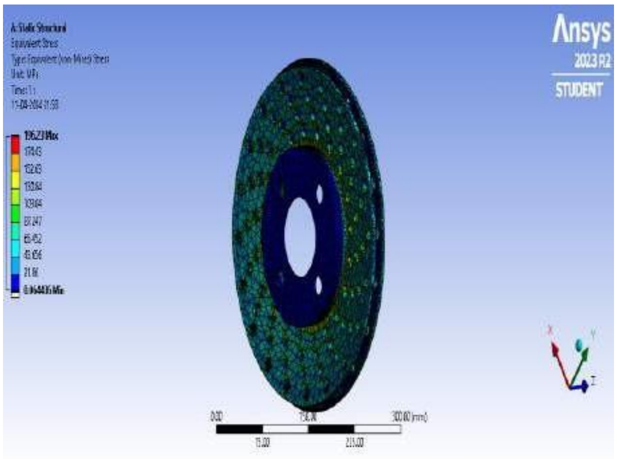
## (2) <u>Drilled disc brake</u>

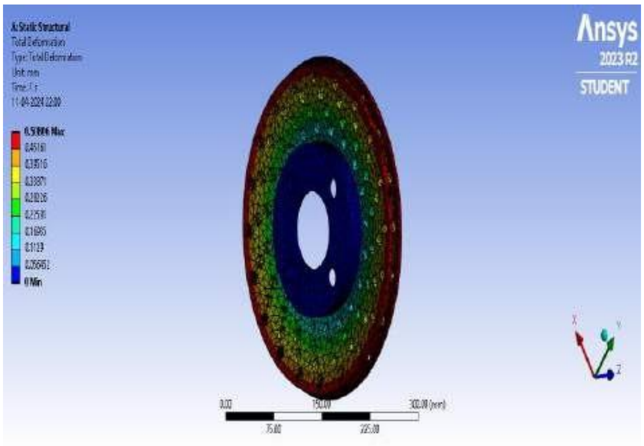
### (a) Aluminium metal matrix

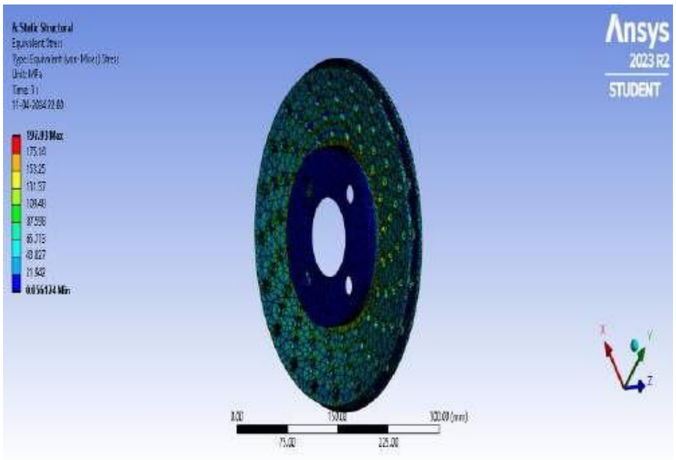



The above figures display the Total deformation and Equivalent (von-Mises) stress of Drilled disc brake made of Aluminium. As it is evident from the figures, the maximum total deformation and equivalent (von-Mises) stress are represented by red colour and the values being, 0.559 mm and 196.23 MPa respectively.

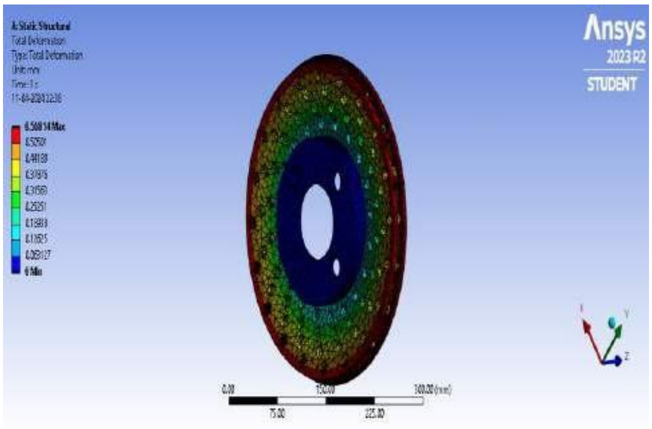
### (b) Gray Cast Iron

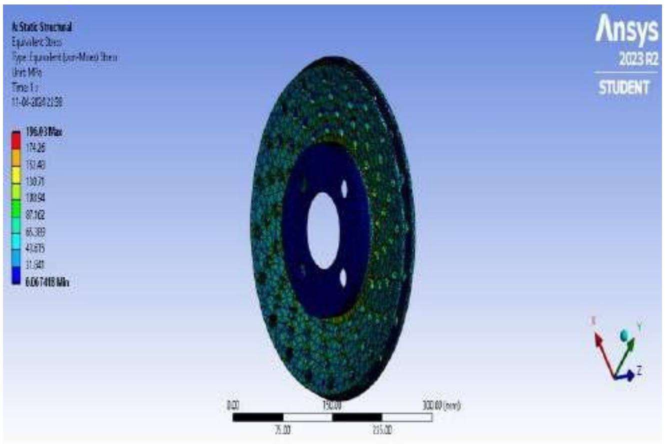



The above figures display the Total deformation and Equivalent (von-Mises) stress of Drilled disc brake made of Gray Cast Iron. As it is evident from the figures, the maximum total deformation and equivalent (von-Mises) stress are represented by red colour and the values being, 0.508 mm and 197.03 MPa respectively.

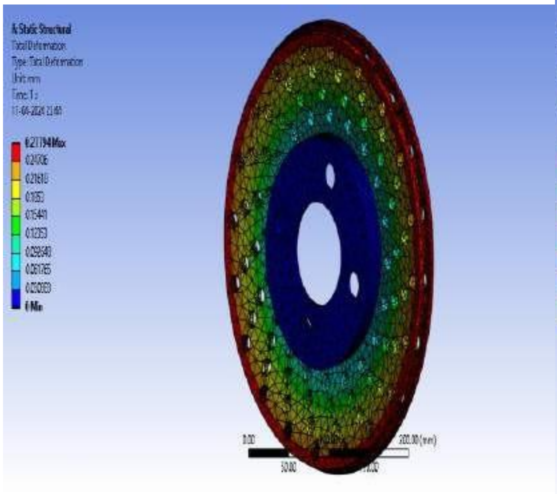
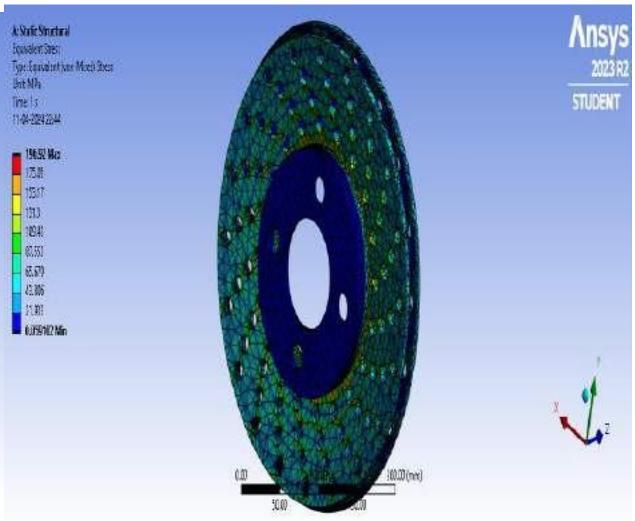
**(c) Titanium Alloy**





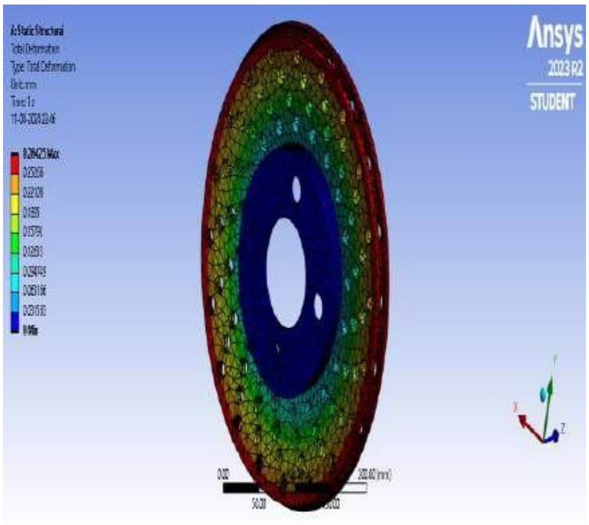

The above figures display the Total deformation and Equivalent (von-Mises) stress of Drilled disc brake made of Titanium alloy. As it is evident from the figures, the maximum total deformation and equivalent (von-Mises) stress are represented by red colour and the values being, 0.568 mm and 196.03MPa respectively.

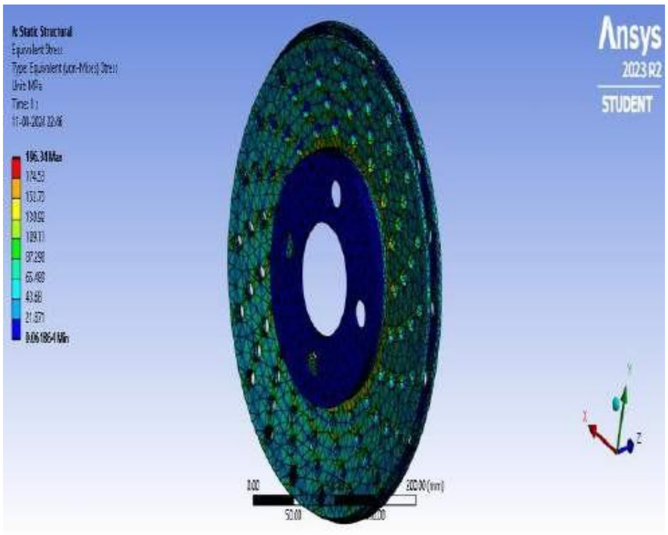
**(d) Structural steel**


The above figures display the Total deformation and Equivalent (von-Mises) stress of Drilled disc brake made of Structural Steel. As it is evident from the figures, the maximum total deformation and equivalent (von-Mises) stress are represented by red colour and the values being, 0.277 mm and 165.48 Mpa respectively.

**(e) Carbon ceramic**

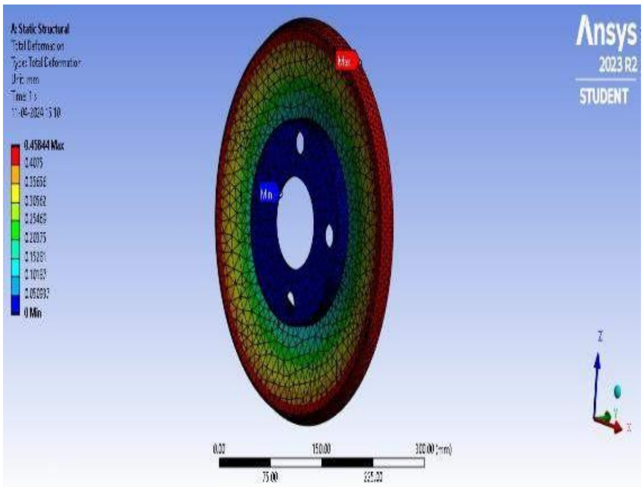


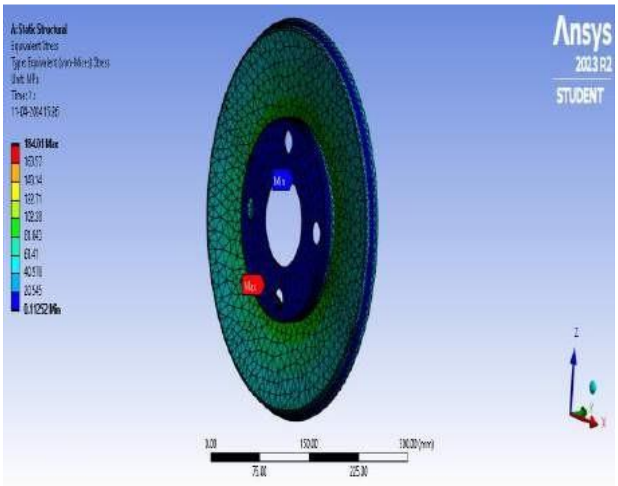



The above figures display the Total deformation and Equivalent (von-Mises) stress of Drilled disc brake made of Carbon Ceramic. As it is evident from the figures, the maximum total deformation and equivalent (von-Mises) stress are represented by red colour and the values being, 0.284 mm and 196.34 MPa respectively.

## (3) <u>Solid disc brake</u>

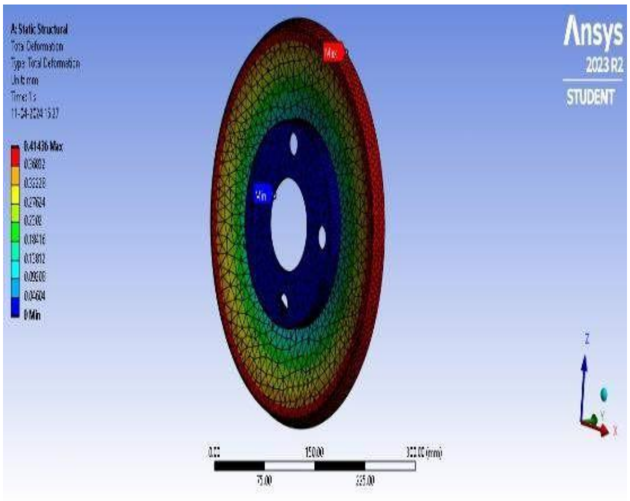
**(a) Aluminium metal matrix**

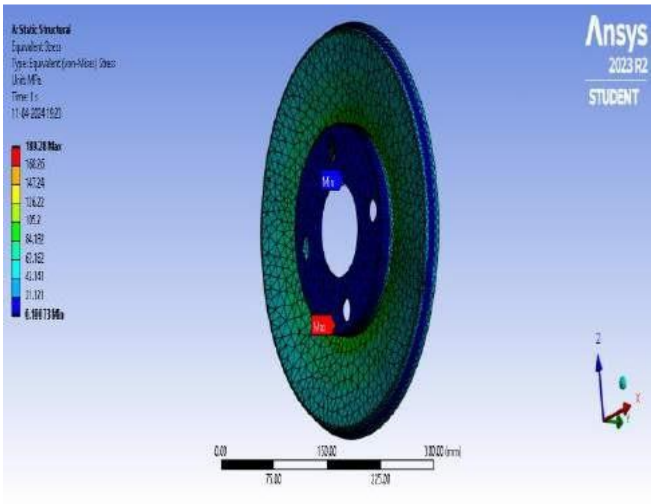





The above figures display the Total deformation and Equivalent (von-Mises) stress of Solid disc brake made of Aluminium. As it is evident from the figures, the maximum total deformation and equivalent (von-Mises) stress are represented by red colour and the values being, 0.458 mm and 184.01 MPa respectively.

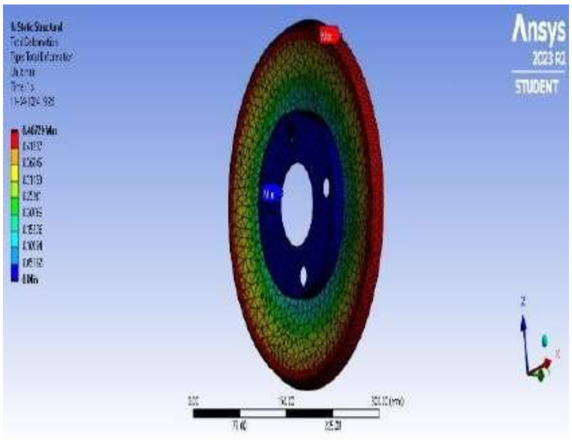
**(b) Gray Cast Iron**

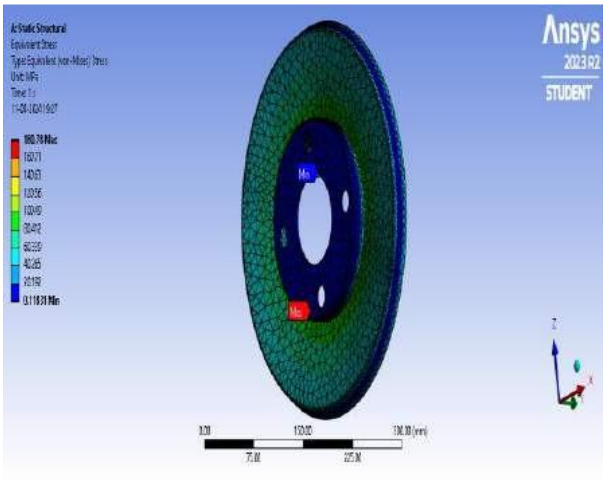



The above figures display the Total deformation and Equivalent (von-Mises) stress of Solid disc brake made of Gray Cast Iron. As it is evident from the figures, the maximum total deformation and equivalent (von-Mises) stress are represented by red colour and the values being, 0.414 mm and 189.28 MPa respectively.

**(c) Titanium Alloy**




The above figures display the Total deformation and Equivalent (von-Mises) stress of Solid disc brake made of Titanium Alloy. As it is evident from the figures, the maximum total deformation and equivalent (von-Mises) stress are represented by red colour and the values being, 0.467 mm and 180.78 MPa respectively.

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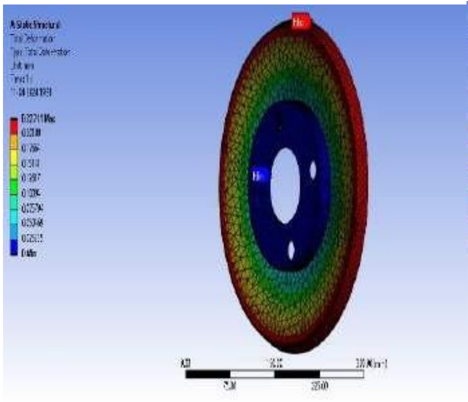
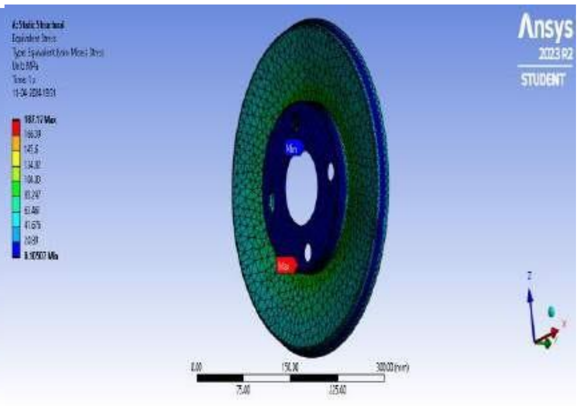
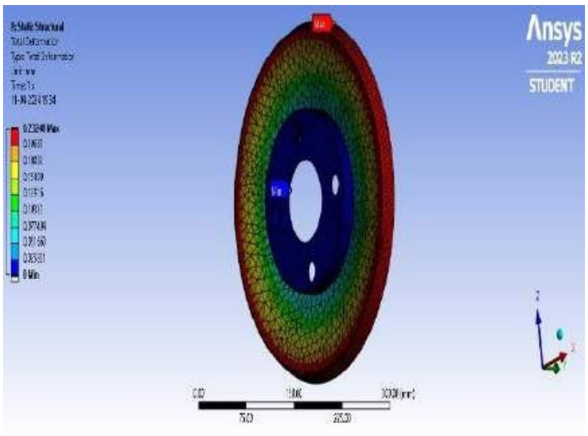
**(d) Structural steel**

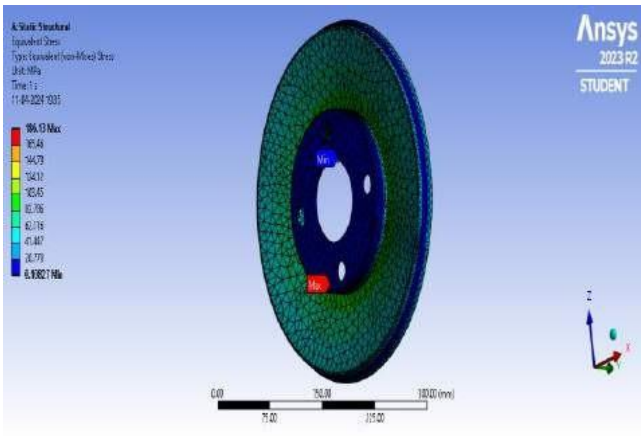





The above figures display the Total deformation and Equivalent (von-Mises) stress of Solid disc brake made of Structural steel. As it is evident from the figures, the maximum total deformation and equivalent (von-Mises) stress are represented by red colour and the values being, 0.227mm and 187.17 MPa respectively.

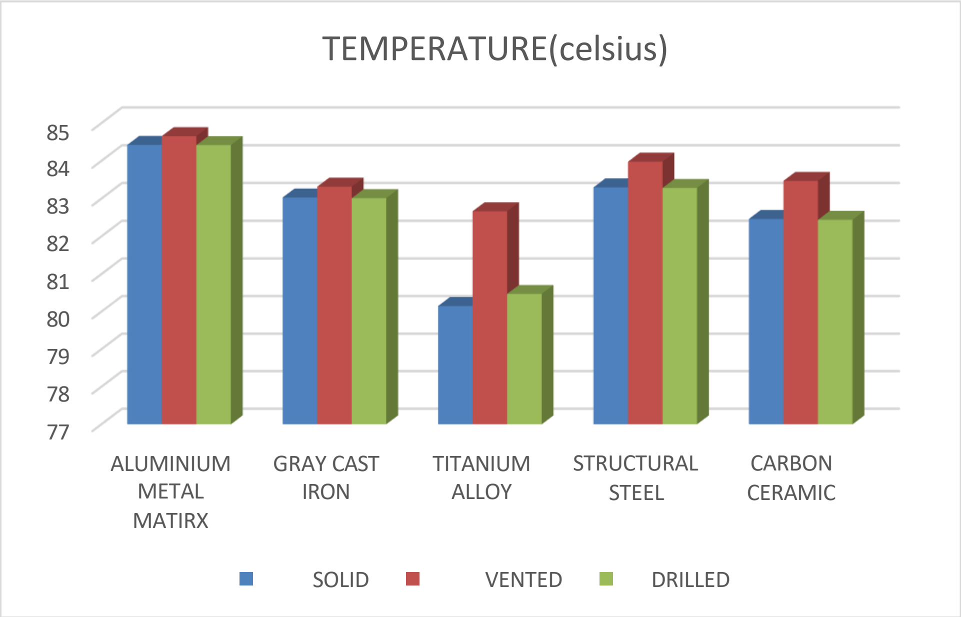
**(e) Carbon ceramic**



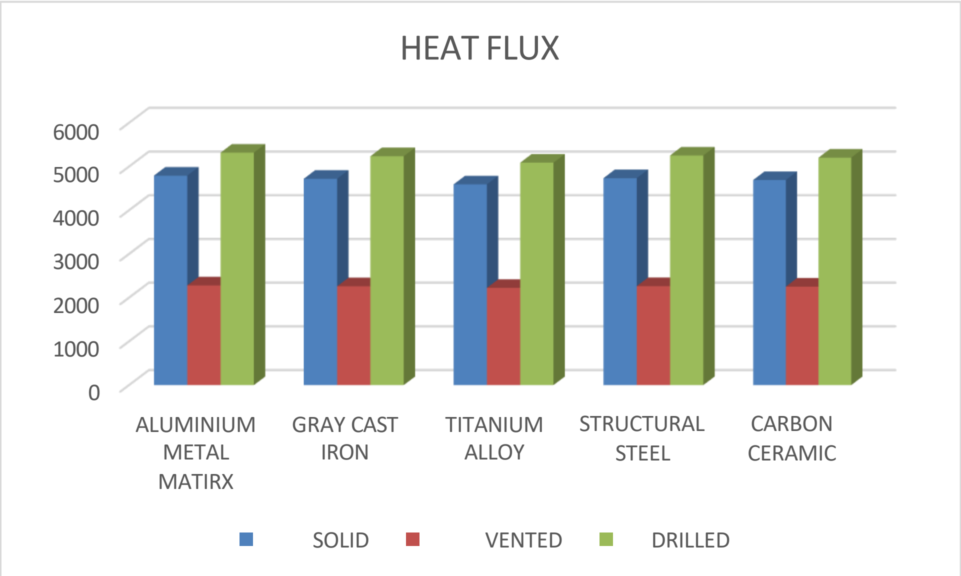




The above figures display the Total deformation and Equivalent (von-Mises) stress of Solid disc brake made of Carbon Ceramic. As it is evident from the figures, the maximum total deformation and equivalent (von-Mises) stress are represented by red colour and the values being, 0.232 mm and 186.13 MPa respectively.

**GRAPHS**

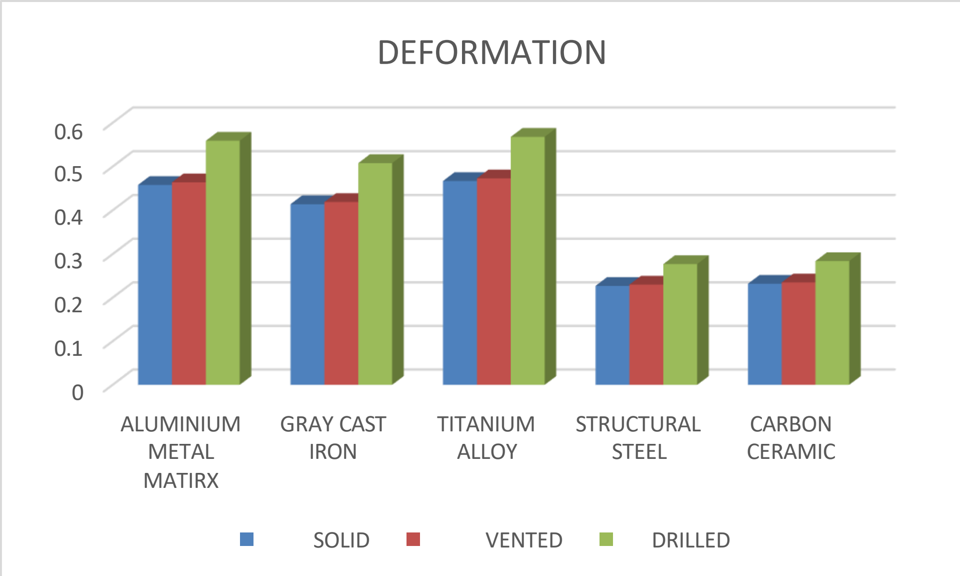



(a)

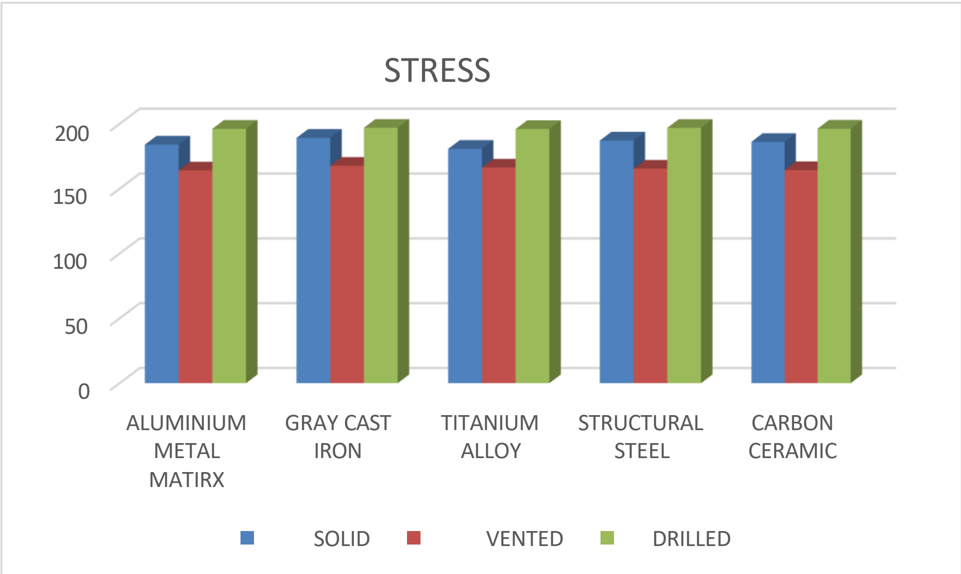



(b)

Thermal analysis of solid, vented and drilled disc brake for different materials { (a) & (b) }




(a)




(b)

Structural analysis of solid, vented and drilled disc brake for different materials { (a) & (b) }

### 6.4 COMPARISON OF RESULTS

**THERMAL ANALYSIS**

**TEMPERATURE ANALYSIS:**

| MATERIAL | SOLID | VENTED | DRILLED |
|---|---|---|---|
| ALUMINIUM METAL MATIRX | 84.424 | 84.656 | 84.418 |
| GRAY CAST IRON | 83.031 | 83.317 | 83.013 |
| TITANIUM ALLOY | 80.152 | 82.666 | 80.473 |
| STRUCTURAL STEEL | 83.3 | 83.98 | 83.285 |
| CARBON CERAMIC | 82.463 | 83.471 | 82.44 |

**Heat Flux Analysis:**

| MATERIAL | SOLID | VENTED | DRILLED |
|---|---|---|---|
| ALUMINIUM METAL MATIRX | 4791.9 | 2280.4 | 5318.6 |
| GRAY CAST IRON | 4720.5 | 2260.9 | 5236.9 |
| TITANIUM ALLOY | 4591.7 | 2225 | 5089.8 |
| STRUCTURAL STEEL | 4734.3 | 2264.7 | 5252.7 |
| CARBON CERAMIC | 4691.5 | 2252.9 | 5203.7 |

The results of the three materials: Aluminium metal matrix, Gray Cast Iron, Titanium alloy, Structural steel and Carbon ceramic shows that Solid type disc brake made of Titanium alloy gives less temperature value when the loads are applied. Therefore, Solid type disc brake made of Titanium alloy material is preferred.

**Deformation Analysis:**

**STRUCTURAL ANALYSIS**

| MATERIAL | SOLID | VENTED | DRILLED |
|---|---|---|---|
| ALUMINIUM METAL MATIRX | 0.458 | 0.464 | 0.559 |
| GRAY CAST IRON | 0.414 | 0.419 | 0.508 |
| TITANIUM ALLOY | 0.467 | 0.473 | 0.568 |
| STRUCTURAL STEEL | 0.227 | 0.23 | 0.277 |
| CARBON CERAMIC | 0.232 | 0.235 | 0.284 |

**Stress Analysis:**

| MATERIAL | SOLID | VENTED | DRILLED |
|---|---|---|---|
| ALUMINIUM METAL MATIRX | 184.01 | 164.13 | 196.23 |
| GRAY CAST IRON | 189.28 | 167.72 | 197.03 |
| TITANIUM ALLOY | 180.78 | 166.34 | 196.03 |
| STRUCTURAL STEEL | 187.17 | 165.48 | 196.92 |
| CARBON CERAMIC | 186.13 | 164.34 | 196.34 |

The results of the three materials: Aluminium metal matrix, Gray Cast Iron, Titanium alloy, Structural steel and Carbon ceramic shows that Vented type disc brake made of Carbon ceramic gives less deformation & Stress value when the loads are applied. Therefore, Vented type disc brake made of Carbon ceramic material is preferred.

## 7. *CONCLUSION*

1. Solid type disc brake made of Titanium Alloy material is preferred for minimum temperatures.
2. Drilled type disc brake made of Alluminium metal matrix is preferred for higher heat flux distribution.
3. Solid type disc brake made of Carbon ceramic material is preferred for lesser deformation.
4. Vented type disc brake made of Alluminium metal matrix material is preferred for lesser von-misses stresses.

In order to improve the braking efficiency and provide greater stability to the vehicle, an investigation is carried out into the usage of materials. In this project, we presented the thermal and structural analysis of solid,drilled and ventilated type disk brake. We have shown that the ventilation system plays an important role in cooling the discs and provides a good high temperature resistance. The analysis results showed that, temperature field and stress filed in the process of braking phase were fully coupled.
Static structural analysis is carried out by coupling the thermal solution to the structural analysis. The present study can provide a useful design tool and improve the brake performance of disc brake system. From the above Tables, we can say that all 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. Comparing the different results obtained from analysis, it is concluded that **ventilated type disc brake** is the best possible for the present application. By observing analysis results, it is concluded that **Carbon ceramic** is the best material for Disc brake.

## 8. *FUTURE SCOPE OF THE PROJECT*

There is a significant scope for further work and this is summarised below:

➢ In the present investigation of Thermal analysis of disc brake, a simplified model of the disc brake without any vents with only ambient air cooling is analyzed by FEM package ANSYS. As a future work, a complicated model of Ventilated disc brake can be taken and there by forced convection is to be considered in the analysis. The analysis still becomes complicated by considering variable thermal conductivity, variable specific heat and non uniform deceleration of the vehicle. This can be considered for the future work.

➢ A full 3D analysis of the brake disc including the pads should be considered in order to investigate the effects of rotating heat source and the non-uniform heat flux over the rubbing surfaces due to non-uniform pressure distributions.

➢ A programme of experimental work needs to be undertaken using a full size dynamometer since it can subject the brake to the same sequence of high energy stops that has been modelled in the numerical situation. This will provide the necessary data to validate the model and provide an indication of the location of possible fracture sites.

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