

# International Journal of Innovative Research in Science, Engineering and Technology

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## Design and Analysis of Brake Disc

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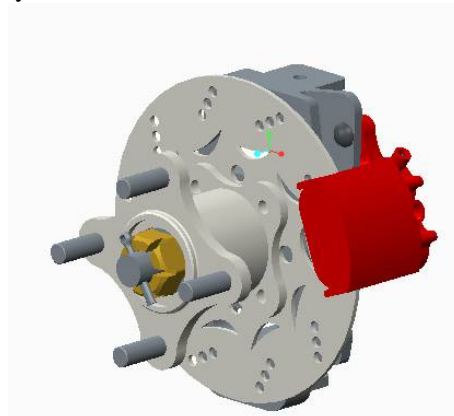
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**ABSTRACT:** These days almost every motorcycle is equipped with hydraulically actuated disc brakes as well as the race cars use these brake rotors. The system is convenient as it compact and efficient. The discs used in this system helps to stops the vehicle in very less time with the help of calliper pads. The calliper pads are connected to the pistons of the calliper which are actuated by hydraulic force generated by the hydraulic fluid. The heat is generated during the process of stopping. Hence the disc must be made with a material that will withstand at such high temperatures. Here the disc is designed according to the requirement and analysed under transient thermal condition in ANSYS workbench 18.1.

**KEYWORDS:** DISC BRAKES, CALLIPERS, HYDRAULIC, ANSYS 18.1.

### I. INTRODUCTION

The objective of the study is to design and analyse the brake discs that can be used in a race cars. The brake disc is used to stop the car/motorcycle with the help of calliper pads. The calliper pads are actuated by a fluid present in the hydraulic circuit. The wheel assembly of the car consists of knuckle (upright), stubb, hubs, bearings and disc [4]. The brake discs are mounted on the hub which is connected to the wheels directly. The disc is mounted behind the hub. The knuckle have a special arrangement for mounting a calliper on it. The part of the disc is inserted in the space present between the calliper pads. The part of the disc which is in contact with the calliper pads is known as pad area on the disc. Figure 1 shows the wheel assembly of the car.



**Fig.1 Wheel assembly of the car (calliper in red & brake disc in white) [6]**

The disc have to be manufactured with a material which can withstand at high temperature generated due to the friction between the disc and pads. With the material selection the brake disc geometry plays an important role. The disc diameter is fixed according to the brakes calculation and the stopping distance that is required. As discussed earlier the disc is mounted on the hub, the PCD (Pitch circle diameter) of the disc that will be specified according to the hub. With

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the material selection the geometry of the disc plays an important role. In the OEM (Original Equipment Manufacturer) discs the holes in the specific pattern can be seen. The holes are present on the disc for a various reasons like-

- Heat dissipation from the disc
- Weight reduction
- Aesthetics

The iterative method can be used for the accurate design and analysis of the disc. The disc with various pattern can be designed and after that it can be analysed for the temperature distribution, thermal stress and combined stresses induced in the disc due to moment and braking force which act directly on the disc while braking

## II. DESIGN METHODOLOGY

As discussed earlier before starting the design various parameters like disc diameter, PCD of the disc and thickness of the disc as well as the callipers to be is to be finalised.

Disc diameter – 190 mm

PCD of the Disc – 78 mm

Size of bolts- M8 (8.8 grade with metal lock nuts)

Thickness of the disc- 3 mm

Callipers- Will wood double piston floating callipers

Consider the 30 mm patch on the disc as a pad area.

By considering the above parameters 4 different discs with different geometry is designed. Figure 2 shows the 4 different types of the disc.

All above parameters are considered according to the dynamic requirements of the car.

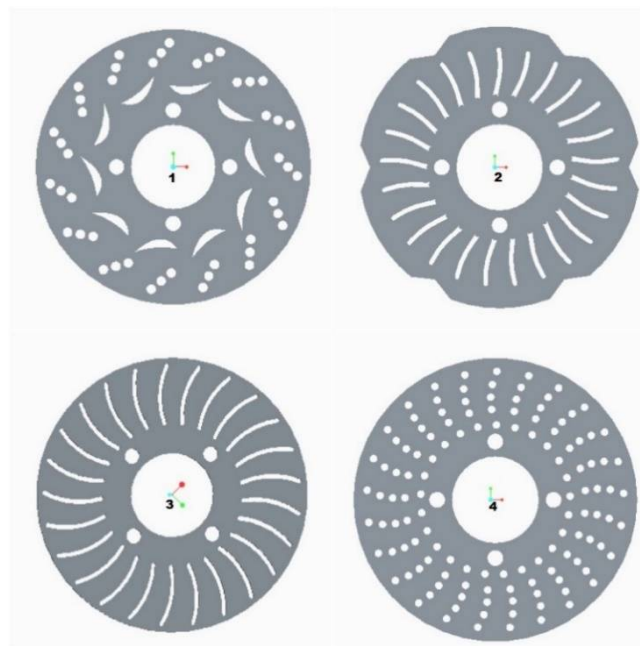


Fig.2 CAD model of different types of discs which are designed according to the specified conditions

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### III. MATERIAL SELECTION

As discussed earlier the material selection plays an important role in the safety as well as the reliability of any component. According to the application the material of the disc is selected. The material that is to be used should have high temperature resistance, good frictional properties, resistance to fatigue failure etc. Various options available for brake disc material

- Aluminium metal matrix composites (AMMC) [3]
- Stainless steel (SUS 410) [3]
- Carbon fibre
- Grey cast iron

All of the above options are widely used in the OEM discs. They have all the desirable properties which are needed for a brake disc. But coming to the cost, the cost of Aluminium metal matrix composites and Carbon fibre is high. The stainless steel provides an advantage of corrosion resistance over Grey Cast iron. As compared to Grey cast iron the cost of stainless steel is high. So the **grey cast iron** is selected for the disc.

PROPERTIES	VALUE
Modulus of elasticity	124 GPa
Thermal expansion (20 °C)	9.0*10 <sup>-6</sup> °C <sup>-1</sup>
Specific heat capacity (25 °C)	490 J/(kg*K)
Thermal conductivity	53.3 W/(m*K)
Fatigue strength	138 MPa

Table no.1 Thermal properties of Grey cast iron [1]

### IV. CALCULATIONS

For analysing the discs some assumptions are to be done as well as calculation of some parameters are required.

Assuming mass of the car is 300 kg (a race car). Now considering that the car is travelling at a speed of 100km/h on a race track (Formula race track) and it suddenly applies a brake which decelerates the car and at the end the car stops. During the FEA thermal analysis this case will be simulated. After the simulation in the transient thermal model, the temperature distribution on the pad area, as well as the maximum temperature value can be noted. As discussed in the earlier sections proper heat dissipation from the disc surface should be there.

Initial temperature (ambient temperature) – 22 °C

Velocity- 100 km/hr / 22.22 m/s

Mass (M) - 300 kg Weight – 300\*9.81= 2943N

Coefficient of friction between road and tyre ( $\mu$ ) - 0.8 [2]

Frictional Force (Ff) =  $\mu mg = 0.8*300*9.81= 2354.4$  N

By Newton's 2<sup>nd</sup> law

F= MA

Let Ax be the average deceleration during braking.

Considering Final Velocity of car- 0 m/s

Ax = Ff/M

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$2354.4/300 = 7.848 \text{ m/s}^2$ ,  $dv$  – change in velocity =  $-22.22 \text{ m/s}$  (deceleration)

Time required to stop (t) =  $dV/Ax = -22.22/7.848 = 2.831 \approx 3 \text{ s}$

Now heat transfer from the disc will take place by three modes- conduction convection and radiation. For this analysis radiation factor is not considered.

$Q_{\text{convective}} = hA(\Delta T)$  where  $h$  convective heat transfer coefficient,  $A$  is the exposed surface area,  $\Delta T$  is the temperature difference

Convective heat transfer coefficient from disc to air is taken as  $90 \text{ Wm}^{-2}\text{K}^{-1}$ .

When brakes are applied due to the action of fluid present in the hydraulic circuit the piston moves, as pistons are attached to the brake pads, they push the one of the brake pad which makes a contact with the rotating disc. The pad tries to stop the disc due to which the friction is generated between the pads and disc. Due to this friction the heat is generated on the pad area of the disc. Hence it can be concluded that the kinetic energy of the car is converted into the heat energy during braking.

Kinetic energy = Heat energy

$\frac{1}{2} MV^2 = \frac{1}{2} * 300 * 22.22^2 = 74.059 \text{ KJ}$

Heat power/Heat load =  $KE/t = 74.059/3$

$= 24.686 * 10^3 \text{ W}$

As only one side of disc is considered hence the total heat power =  $24686/2 = 12340 \text{ W}$

But the weight distribution of the car is 40 % in front and 60 % in rear. For front

Heat power =  $12340 * 0.4 = 4936 \text{ W}$

Hence the above conclusion heat load is applied on the pad area during the transient thermal analysis.

## V. THERMAL ANALYSIS

The thermal analysis of the disc is done in Ansys workbench 18.1 under the transient thermal module. As 4 iterations are to be done, in order to get an appropriate results the pre-processing in all 4 iterations to be done with same setting.

Pre-processing setting

- Mesh/Grid size – 3 mm
- Mesh method – Hex dominant
- Mesh type – Adaptive (fine)

The figure 3 shows the mesh type that is to be used for all iteration. As the pre-processing parameters are in all 4 iterations are same, hence the results can be compared with each other to get the appropriate result.

The heat load is applied on the pad area region. As the analysis is transient analysis in which the time step is to be provide. For the analysis 5 time steps are provided. It will calculate the temperature for 7 s. The time step gives an idea about how will be the temperature distributed within a specific given time step

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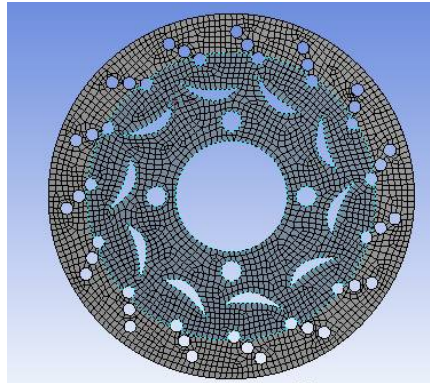


Fig.3 Meshed brake disc

## ITERATION 1

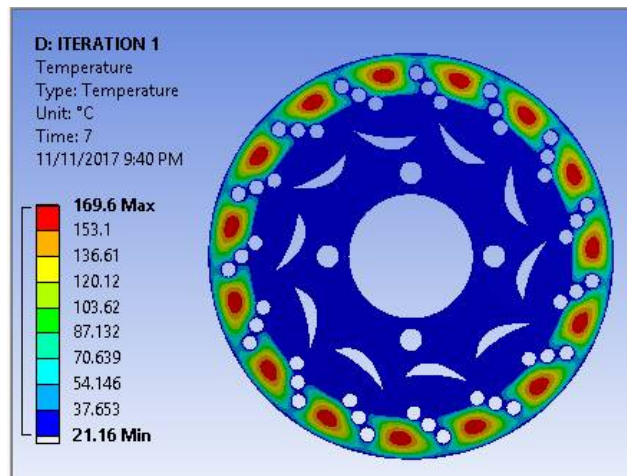


Fig.4 Temperature distribution over the disc for iteration 1

From figure 4 it can be seen that the maximum temperature reached during the specified time step is 169.6 °C. As discussed in the earlier section the use of the holes present on the disc can be seen. It can be seen that the temperature is minimum at the holes. This is due to the heat dissipation that occurs from the holes present on the disc. If the no. of holes present on the disc increases the structural strength of the disc decreases. In order to have optimum no. of holes this thermal analysis plays an important role. The main aim of this analysis is to reduce the value of maximum temperature by increasing the heat dissipation through the holes or the slots which are made on the disc, as well as keeping the strength of the disc appropriate so that it will not undergo structural failure during the panic braking condition.

In order to have a disc with all desirable properties the iterative method can be used.

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## ITERATION 2

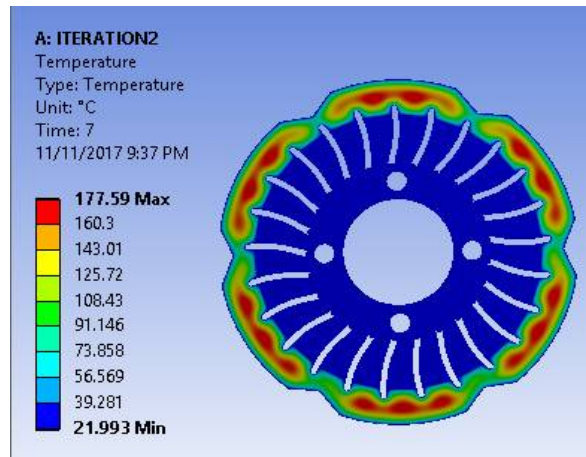


Fig.5 Temperature distribution over the disc for iteration 2

From the figure 5 it can be seen that the maximum temperature reached during the specified time step is 177.59 °C. This type of disc is known as petal type disc.

## ITERATION 3

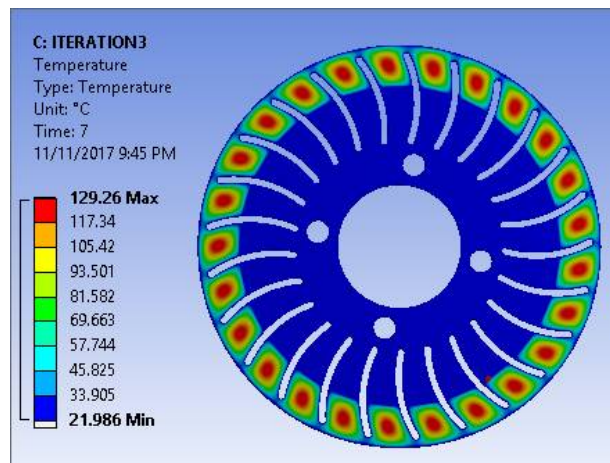


Fig.6 Temperature distribution over the disc for iteration 3

From figure 6 it can be seen that the maximum temperature reached during the specified time step is 129.26 °C

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## ITERATION 4

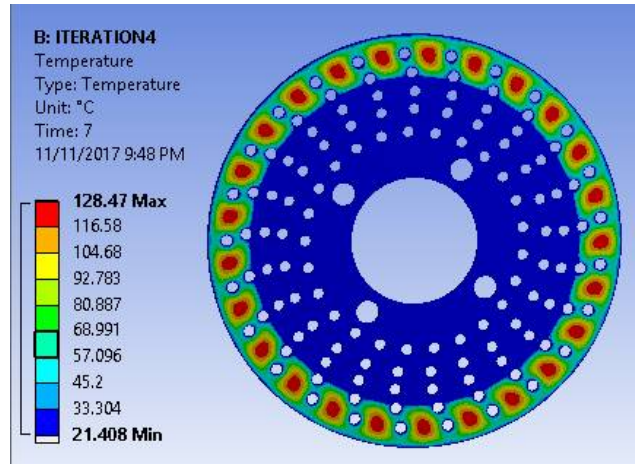


Fig.7 Temperature distribution over the disc for iteration 4

From figure 7 it can be seen that the maximum temperature reached during the specified time step is 128.47 °C.

## RESULT TABLE

ITERATION NO.	MAXIMUM TEMPERATURE
1	169.6 °C
2	177.59 °C
3	129.26 °C
4	128.47 °C.

TABLE NO. 2 Result table for maximum temperatures

From the table no.2 it can be seen that the maximum temperature for iteration 3 and iteration 4 is less as compared to the iteration 1 and iteration 2. From the temperature contour of the both 3 and 4 it can be seen that there is proper temperature distribution in the pad area region. The value of maximum temperature is also low. So both the discs can be used for the braking purpose. But before concluding the superiority of these 2 discs, they must be checked for the structural safety. The analysis which calculates the combined effect thermal conditions as well as structural conditions is known as **thermo-structural analysis**.

For this analysis the temperature load results are imported into in the static structural module. Structural loads which are to be applied on the disc are Braking force and moment.

Braking force = 500 N on pad area

Moment = 150000 N.mm applied on whole disc

Fixed support is applied on 4 inner holes of the disc

After this analysis we will get the values of the combined stress induced in the disc while during braking.

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## FINAL ITERATION 3

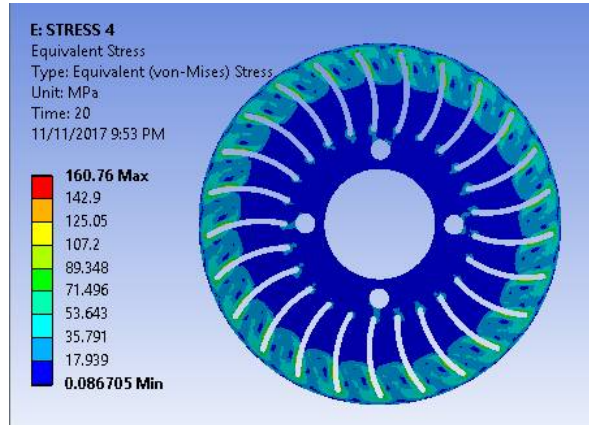


Fig.8 Combined stress induced in the disc for iteration 3

From figure 8 it can be seen that the maximum stress induced during the specified time step is 160.76 MPa.

## FINAL ITERATION 4

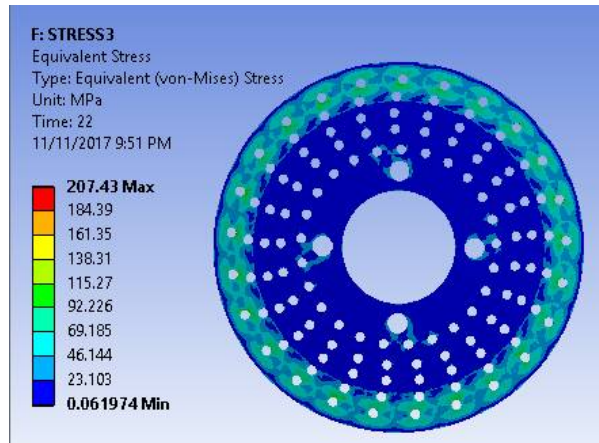


Fig.9 Combined stress induced in the disc for iteration 4

From figure 9 it can be seen that the maximum stress induced during the specified time step is 207.43 MPa.

From the above two results it can be concluded that more combined stress is induced in iteration. Factor of safety for the disc is **1.492**. Hence **disc no. 3 can be used in the car**.

## VI. CONCLUSION

It can be concluded that the iterative method that is used in the design procedure of the brake disc is an efficient way, by the analysis on all 4 discs the suitable and the best disc can be selected. Hence the selected disc have good heat



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dissipation capacity as well as the combined stress induced due to temperature and forces on the disc are also low. Hence the best disc for the race car application is been selected after the iterative analysis method.

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