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# ANALYSIS AND OPTIMIZATION OF DISC BRAKE ROTOR

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## ABSTRACT
In Today's fast moving world automobile is the main mode of transport and its safety is concerned most. So, we have selected to do Analysis and Optimization of Disc Brake Rotor to increase the performance of disc brake rotor. Generally Disc Brake Rotor is manufactured by using the materials Cast Iron, Aluminum, steel, composite ceramics, silica carbide. Goal is to Get high performance Disc Brake Rotor by analyzing and manufacturing the disc brake rotor by using different material. Disc Brake Rotor model is designed and analyzed in CAD /CAM packages (Pro-e and Ansys). Disc Brake Rotor is the main part of a braking system in automobile, as pads in braking system are rubbed against the brake rotor to create friction and there by stopping the vehicle. So, in this project main aim is to design the Disc Brake Rotor which gives high performance than the present disc brake rotor.

**KEYWORDS**: Disc brake rotor, Grey Cast Iron, Ductile Cast Iron, Analysis.

## INTRODUCTION
A brake is an equipment that stop the motion of a moving member by making use of artificial frictional resistance. While performing this function, the brakes imbibe potential energy(P.E) or kinetic energy(K.E) of the moving member. The energy which is absorbed by the brakes is dissipated in the form of heat. In turn the dissipated heat is liberated into the surrounding atmosphere

## LITERATURE REVIEW
A brake is a device which helps in reducing the speed or stopping the motion of a machine or vehicle, or alternatively a device to restrain it from getting down to move once more. Brakes of some description are fitted to most wheeled vehicles, including automobiles of all kinds of trucks, trains, motorcycles, and bicycles. Baggage carts and shopping carts may have them for use of moving ramp. Some of the airplanes are fitted with wheel brakes on the undercarriage. Some aircrafts also have feature air brakes which are designed to slow them down in flight. Friction brakes on cars store the heat in the rotating part (disc brake/drum brake) during the brake application and releases it to the air gradually. The kinetic energy lost by the moving part is usually transformed to heat by friction. Alternatively, in regenerative braking, most of the energy is recovered and stored in a flywheel or capacitor or turned into alternating current by an alternator, then rectified and stored in a battery for later use.

Kinetic energy (K.E) increases with the square the velocity ($E = (mv^2)/2$). This means that if the speed of a vehicle doubles, it has four times as much energy. By equation it is understood that four times of energy must be dissipate from the brake to stop the vehicle and at the same time four times of breaking distance also be provided. When the brake pedal is pressed, the vehicle's braking system will transmits the force from your foot to its brakes through a fluid. Since the greater force is required by the actual brakes than the leg could apply with, vehicle must also multiply the foot force. This is done in two ways; mechanical advantage (leverage) and hydraulic force multiplication. The brakes transmit the force to tires using friction, and the tires transmit that force to the road using friction also.

From past 100 years researches are going on a breaking system. Normally breaking system consists of disk or drum brakes in rear wheels, disk break in front wheel which is connected to master cylinder. Along with this break system parking brakes, power brake booster & the anti lock system is also induced. When the brake pedal is pressed, it is pushed against the plunger in the master cylinder which will force hydraulic oil (brake fluid) through a series of the tubes and hoses to braking unit at each wheel. It is known that fluids are incompressible whenever we push the fluid it is just act like a steel bar, which is pushing through a pipe. Unlike a steel bar, however, fluid can be directed through many turns and twists on its way to its destination, arriving with the exact same motion and pressure that it is started with. It is very important, that the fluid is of pure liquid and that there is no air bubbles in it. Air can compress which causes springiness to the pedal and severely reduced braking efficiency. If air is suspected, then the system must be bleed to remove the air. The "bleeder screws" are arranged at each wheel cylinder and caliper for this purpose.

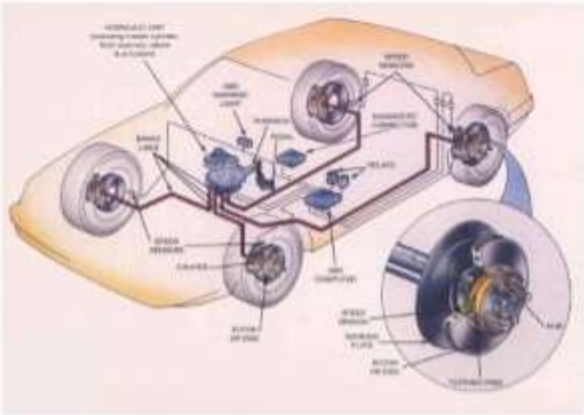

***Fig1.Brake system in automobiles***

The main function of the disc brake rotor is to transmit the mechanical force and dissipate the heat produced which implies to be functioned at the both medium and high temperature. The disc brake rotor provides braking surface or friction surface for brake pads to rub off on it when brake is applied. A rotor is generally made from grey cast iron due to cast iron which provides good wear resistance with high thermal conductivity and the production cost is low compared to other disc brake rotor materials such as carbon composites, Al-MMC and ceramic based composites. Currently, there are two types of disc brake rotors used for passenger car which is a solid disc and the other is ventilated disc.

A solid rotor is a simply of solid piece of metal with frictional surface on each side and this type of rotor is light, simple, easy and cheap to manufacture. A ventilated disc in meanwhile refers to the brake disc or rotor with various opening profiles (grooves, holes etc.) which provide a better cooling performance (additional heat transfer function) and weight savings as well as aesthetic appearance. Therefore, it is widely used compared to solid disc.

The thermal stability of the disc shape is prime factor before designing the disc. The factors which affect the shape of the disc are basic design for the disc rotor, heat treatment before machining and the quantity of the material used for it. The thermal properties which affect the disk brake rotor as follows.

**(1)** **Thermal expansion coefficient:** Due to this property hot spotting and disc thickness variation may occur. The temperature gradients of the disc brake may cause uneven thermal expansion the material.
(2) **Thermal conductivity**: While applying the brake due to friction heat will generated and the intensity of this heat is depends on duration of the brake applied. And this generation of heat is directly proportional to thermal conductivity of the material. During long and low intensity braking the peak temperature will depend largely on the disc material conductivity.
(3) **Heat dissipation**: During short braking small amount of heat will be generated which will not affect the brakes. But during long braking heat generated will be more and this heat has to be dissipated in short interval of time. Otherwise it will affect the disc material.
(4) **Thermal capacitance**: It is the property of material able to store the heat. During breaking process a small amount of frictional heat is stored and while short braking this thermal capacitance dominates.

## MODELLING AND ANALYSIS
### Model of a disc brake rotor

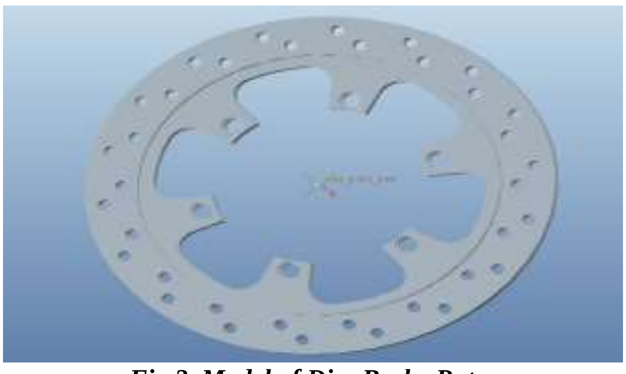

***Fig 2. Model of Disc Brake Rotor***

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**Design specifications**
**TABLE I**

***OVERALL SPECIFICATIONS OF THE DISC BRAKE***

| | |
|---|---|
| Dia of disc | : 240 mm |
| Thickness of disc | : 5 mm |
| Dia of bolts | : 12 mm |
| No. Of bolt circles | : 6 |
| Dia of holes | : 7 mm |
| No of holes | : 18 |
| Angle between the holes | : 20 |
| Dia of centre pocket | : 170 mm |

**Assumption made to anlyze the disc:**

- Brakes are applied on Two and Four wheels.
- Thickness of 5mm is considered for all the models.
- This analysis does not determine the life of the disc brake
- The disc brake model used is of solid type.
- The thermal conductivity of the material is uniform throughout.
- The specific heat of the material is constant throughout and does not change with the temperature.
- The kinetic energy of the vehicle is lost through disc brakes i.e. there is no heat loss between the tire and the road side.

**Material properties**
**TABLE II**

***PROPERTIES OF THE MATERIALS***

| **Property** | **Grey cast iron** | **Ductile cast iron** |
|---|---|---|
| Young's Modulus | 102 GPa | 172 GPa |
| Density | 7.06*10^3 Kg/m$^3$ | 7.2*10^3 Kg/m$^3$ |
| Poisson Ratio | 0.28 | 0.3 |
| Elongaition | 1% | 3% |
| Specific Heat | 450 J/Kg-k | 460 J/Kg-k |
| Tensile strength | 180 MPa | 830 MPa |
| Yield strength | 110 MPa | 620 MPa |
| Shear strength | 220 MPa | 800 MPa |

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| | | |
|---|---|---|
| Thermal conductivity | 46 W/m-K | 31 W/m-K |
| Thermal Expansion | 10.5µm/m-K | 11µm/m-K |

## RESULT

By seeing the properties of material we can say which one will give the good results, but it is difficult to identify the stress concentration and deformation in a particular part without analyzing it. The below pictures shows the deformation, strain an strain graph of grey CI and ductile CI

**Grey Cast Iron**

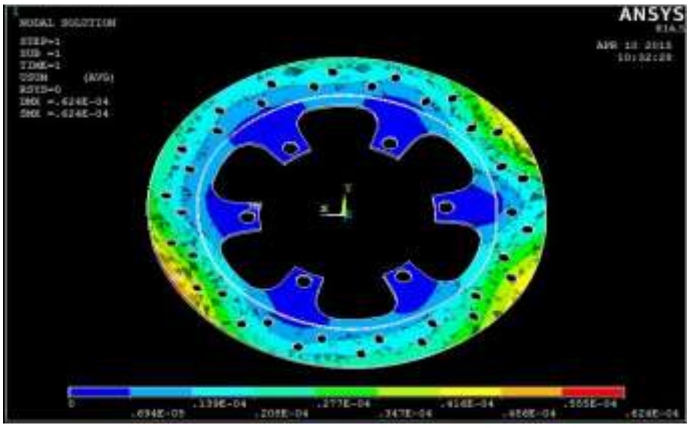


***Fig 3. Deformation of grey CI***

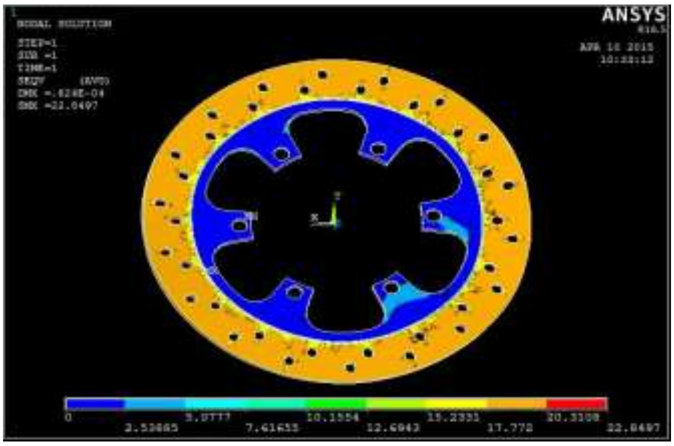


***Fig 4. Stress of Grey CI***

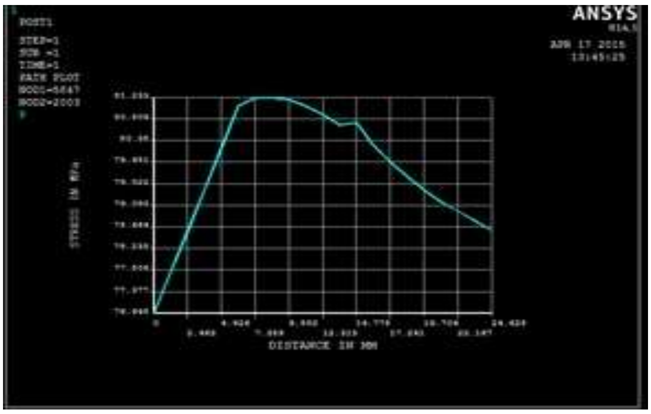


***Fig 5 .Stress Graph***

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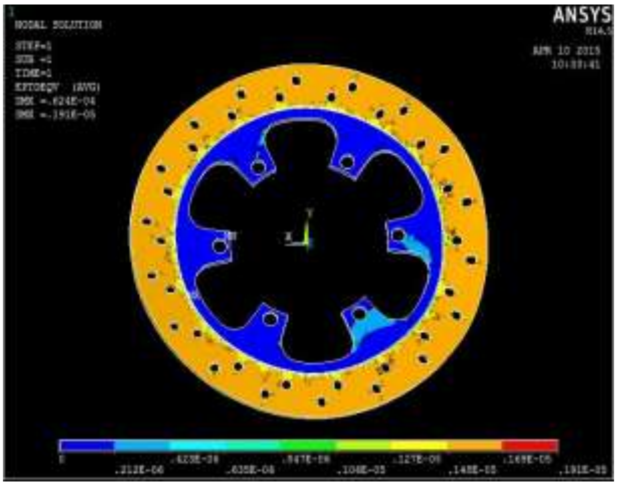

*Fig 6. Strain of Grey CI*

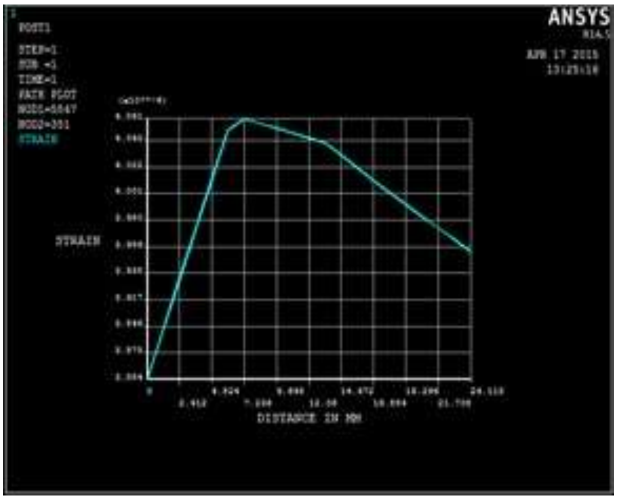

*Fig 7. Strain graph of Grey CI*

The figure 3 shows the deformation is more in periphery of the disc wheel, which is 0.624E-04 mm. The figure 4 shows the uniform stress distribution over the periphery of the wheel. The stress that is acting on the periphery of the disc break is 22.84 MPa. Figure 5 shows the relation between stress and deformation. The maximum stress that is attained is 91 MPa and deformation at this point is 9mm, after this there is sudden change in load with increasing in deformation occurs. Figure 7 shows the relation between strain and deformation.

**Ductile cast iron**

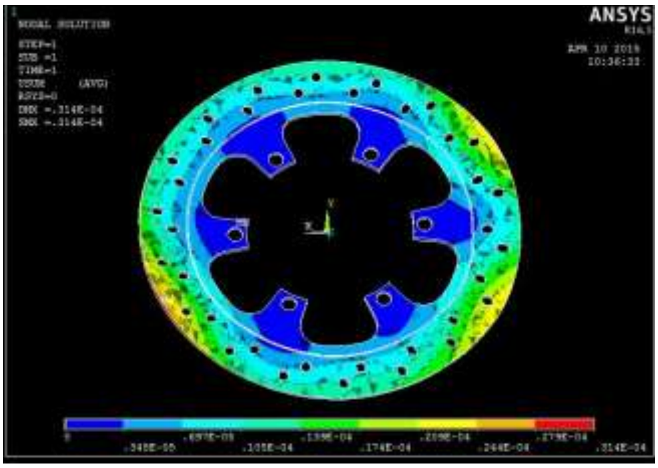

*Fig 8. Deformation of Ductile CI*

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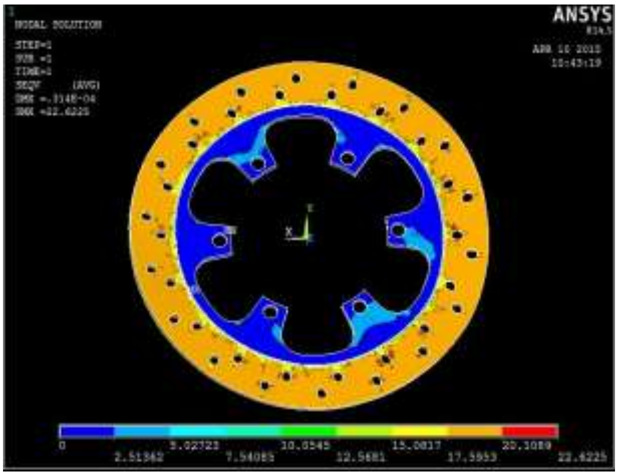


***Fig 9. Stress of Ductile CI***

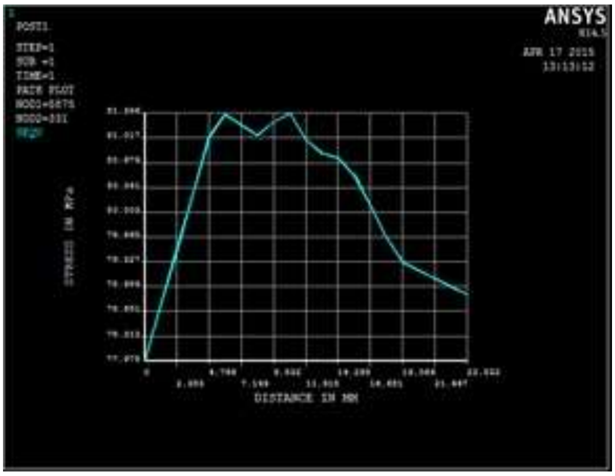


***Fig 10. Stress graph of Ductile CI***

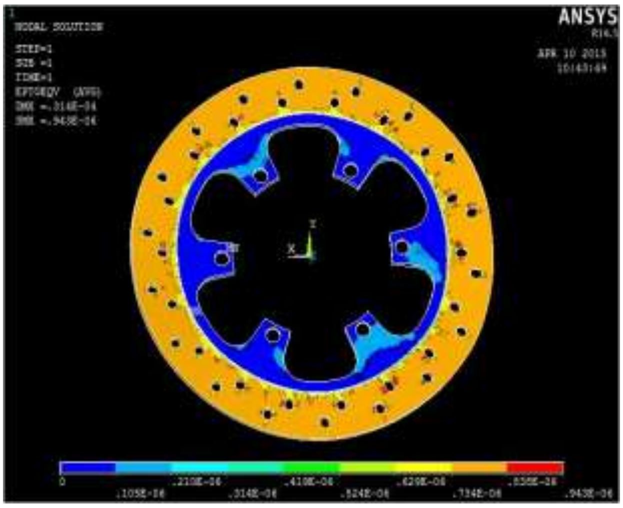


***Fig 11. Strain of Ductile CI***

The figure 8 shows the deformation is more in periphery of the disc wheel, which is 0.31E-04 mm. The figure 9 shows the uniform stress distribution over the periphery of the wheel. The stress that is acting on the periphery of the disc break is 22.62 MPa. Figure 10 shows the relation between stress and deformation. The maximum stress that is attained is 91 MPa and deformation at this point is 6mm and this is carried up to 11mm, after this there is sudden change in load with increasing in deformation occurs. Figure 12 shows the relation between strain and deformation.

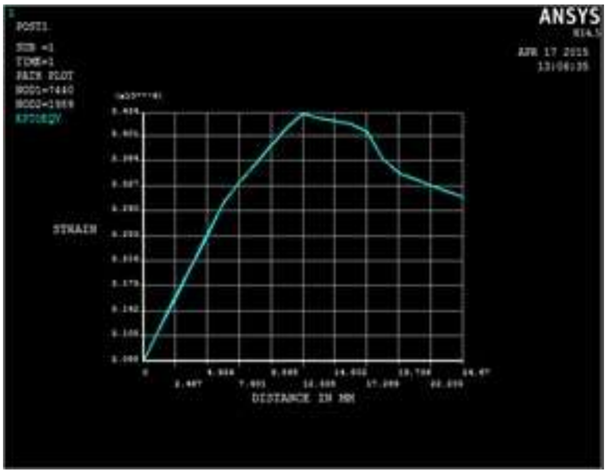


***Fig 12. Strain graph of Ductile CI***

**Result**
**TABLE III**

| *Material* | *Deformation* | *Stress* | *Strain* |
|---|---|---|---|
| GREY CAST IRON | 0.624E-04 | 22.84 | 0.19E-05 |
| DUCTILE CAST IRON | 0.31E-04 | 22.62 | 0.094E-05 |

As performing the analysis for both Grey And Ductile Cast Iron it is noticed that the Stress Concentration is reduced to Ductile Cast Iron. So, we can prefer the Ductile Iron.

## CONCLUSION

Analysis And Optimization of Disc Brake Rotor at all is a very complicated process which involves serious of their processes that are to be designed, analyzed and manufactured. It takes a very long time of thinking of the proper material, proper dimensions, and even proper shape of all different parts. The design of the Disc Brake Rotor is not less complicated process than any other component. Although it the main component used in stopping the vehicle when brake is applied. It was very helpful and used mainly because of its small weight and size.

There are several different stages that I passed until the final Model was completely manufactured. In the way to the end I met lots of difficulties and problem about the way each and every single part is done. Had lots of problems also with the CNC program I used in manufacturing and simulations-PRO-E, ANSYS.

The first stage is about orientation of what the DISC BRAKE ROTOR looks like and how it performs. As I said earlier it was mainly used in application of Brakes and it the very essential part break application device in vehicle.

The Second Stage was about the modeling in PRO-E and start drawings on it. In the beginning it was new for me, although had lots of stuff which are similar to the other CAD/CAM programs. After a week it became easier to me and I could begin with the main theme of the project. Next was start thinking about the shape first and after that the dimensions of part, so each part could fit perfectly on its spot. I passed through lots of problems about that for which it is very much difficult to think about all dimensions and shapes. Finally for me it is very important that the DISC BRAKE ROTOR to be as good.

The Third stage was meeting the analyses in ANSYS. Similar to PRO-E in the beginning it was a new for me and faced a lots of problems in understanding the operations. After that it became easier to me and I begin with the main part of project. Next part was thinking about the type of analyses to be performed on the model. I passed through lots of problems about that it is difficult to perform the meshing and loads acting on it. Finally it is very important to me that based on the required analysis there is change in the performance.

The Last stage was meeting with the manufacturing in CNC Vertical Machining Centre. In the beginning I felt it is most complicated task in understanding the operations to be performed and codes used. As the days passing it

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looks me like a easier job. And the most important thing is the program of the job. After all understanding I started thinking about the project. I finally performed a program of the DISC BRAKE ROTOR and then it is manufactured in the CNC. Finally I have manufactured the DISC BRAKE ROTOR and it looks quite similar to model used in market.

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