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"DESIGN & ANALYSIS OF DISC BRAKE ROTOR BY USING DIFFERENT MATERIALS THROUGH ANSYS"

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ABSTRACT

The disc brake rotor is a rotating device. Braking is a process which converts the kinetic energy of the vehicle into mechanical energy which must be dissipated in the form of heat. This paper presents the analysis of the contact pressure distributions at the disc interfaces using a detailed 3-dimensional finite element model of a real car disc brake roto . Finite element (FE) models of the brake-disc rotor are created using CATIA V5R20 and simulated using ANSYS 17.0 which is based on the finite element method (FEM). It is also investigates different levels in modeling a disc brake rotor system and simulating contact pressure distributions . It covers Finite Element Method approaches in the automotive industry the contact analysis and thermal analysis. The effect of the angular velocity and the contact pressure distribution on disc brake rotor are investigated. In our project we take different materials like Gray Cast Iron, Aluminium Alloy, Titanium Alloy and Composite materials Carbon Fibre. Finally comparison between these materials and carried out stresses and deformations level maximum and minimum then we have find out , Carbon Fiber is the best material than other materials because of its light weight and durablity.

Keyword: *Gray Cast Iron , Aluminium Alloy, Titanium Alloy, Carbon Fiber, Stresses , Deformation, CATIA, ANSYS, Disc brake rotor.*

I. INTRODUCTION

The brakes designed for the purpose of racing need to have very high braking efficiency. The wear and tear of the pads or the cost is not of great concern to the manufacturer of the racing car brakes. Initially the automobiles employed drum brakes in the cars. The main focus of this thesis is not for the passenger car technology but it concentrates on the automotive racing industry, NASCAR, the Nation Association of Stock Car Racing. NASCAR is a racing league similar to other racing leagues like Formula 1. The words "Stock Car" are complete purpose built race cars whose only similarity to the production vehicles replicate in exterior side profile. Major vehicle systems are designed for their specific racing purposes . The chassis used by the racing car is full tube frame while that used on commercial vehicles is made of single body frame. Another difference is the drive train; race versions have eight cylinder engines with rear wheel drive whereas commercial vehicles are four or six cylinder engines with front wheel drive.

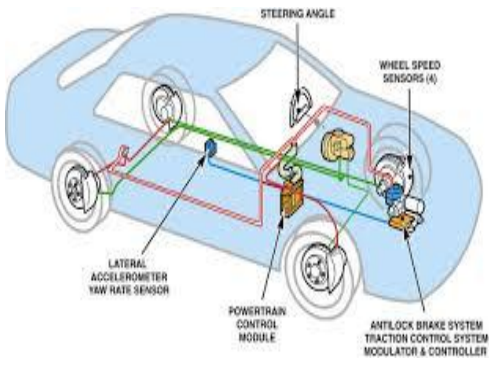

Figure 1.1 Vehicle Brake System

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1.1 How do disc brakes work?

Disk brakes convert kinetic energy from the car into mechanical energy.

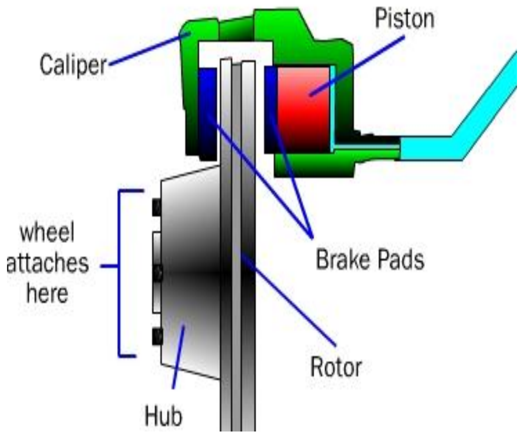

Figure 1.2 Disc brake systems

1.2 Brake Caliper

The brake fluid compresses the piston inside the brake caliper applying pressure to the brake pads.

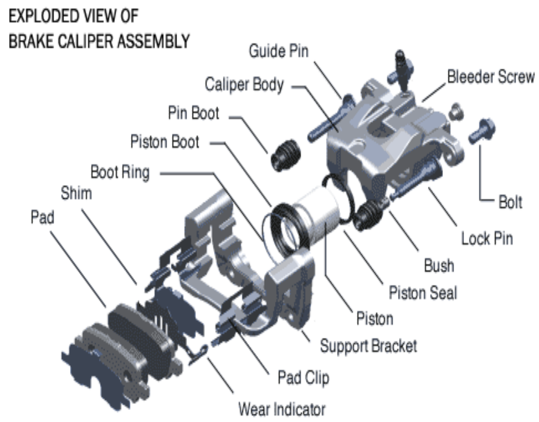

Figure 1.3 Brake Caliper Assembly Systems

1.3 Brake Rotors

- ✓ Connected to the axel – rotating at the same speed as the wheel
- ✓ Generally made out of steel
- ✓ Commonly slotted or drilled for extra heat dissipation


Figure 1.4 Brake Rotor

1.4 Brake Pads

- Fixed in the brake caliper
- Various compounds of materials are used
- Wear over time and must be replaced

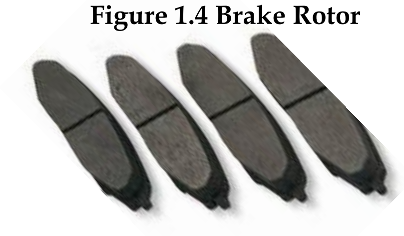
Figure 1.5 Brake Pads

1.5 Brake Pad Materials

- Asbestos
- Semi-Metallic
- Non-Asbestos Organics
- Low Steel
- Carbon
- Exact composition of each manufacturer's pads is a closely guarded secret

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II. Problem in Brake Rotors

On studying the background of brakes the main purpose of conducting this research work was finalized. The main objective was to propose a conceptual design for a disc brake rotor using exiting material Aluminium Alloy, Titanium Alloy, Gray Cast iron and new material Carbon Fiber, called a modular brake rotor. The efficient working of brake system depends on how the brake behaves at high temperatures. Thus the aim of the research work will be to reduce the thermal deformation in the modular brake rotor.

III. Objective

Disc brake noise and vibration generation during braking has been one of the most important issues and definitely worrying problem to automotive manufacturers. Despite brake noise is not a safety issue and has little impact on braking performance, it gives customers the impression of underlying quality problems of the vehicle. In addition, the customers view that the noise emitted from the brake system is indicator of malfunctioning condition and consequently lose confidence on the quality of the vehicles.

IV. Materials

Material selection plays a very important role in machine design. Three materials are considered for the analysis of disc brake rotor Gray Cast Iron, Aluminium Alloy, Titanium Alloy and Carbon Fiber.

Table: 1 Gray Cast Iron Mechanical properties

Material Field Variable	**Value**	**Units**
Density	7200	Kg/m^3
Young's modulus	1.1E+11	Mpa
Poisson Ratio	0.28	
Shear modulus	4.2969E+10	Mpa
Bulk Modulus	8.3333E+10	Mpa
Tensile Strength	240	Mpa
Compressive Strength	820	Mpa
Material Field Variable	Value	Units
Density	7200	Kg/m^3

Table: 2 Aluminium Alloy Mechanical properties

Material Field Variable	**Value**	**Units**
Density	7750	Kg/m^3
Young's modulus	1.93E+05	Mpa
Poisson Ratio	0.31	
Shear modulus	76664	Mpa
Bulk Modulus	1.6937E+05	Mpa
Tensile Yield Strength	207	Mpa
Compressive Yield Strength	207	Mpa
Tensile Ultimate Strength	310	Mpa
Compressive Ultimate Strength	0	Mpa

Table: 3 Carbon Fiber Mechanical properties

Material Field Variable	**Value**	**Units**
Density	1950	Kg/m^3
Young's Modulus	300000	MPa
Poisson Ratio	0.30	
Tensile Strength	5090	MPa
Compressive strength	1793	MPa

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Table: 4 Titanium Alloy Mechanical properties

Material Field Variable	**Value**	**Units**
Density	4620	Kg/m^3
Young's modulus	9.6E+10	Pa
Poisson Ratio	0.36	
Shear modulus	3.528E+11	Pa
Bulk Modulus	1.1429E+11	Pa
Tensile Yield Strength	930	Mpa
Compressive Yield Strength	930	Mpa
Tensile Ultimate Strength	310	Mpa
Compressive Ultimate Strength	1070	Mpa

V. MODELING & SIMULATION

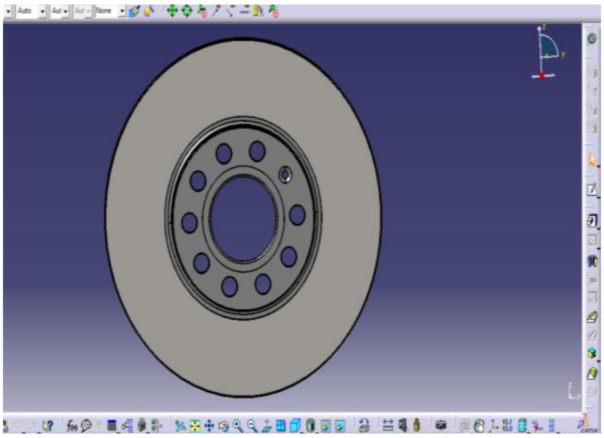

Figure 5.1 CAD Model generated in CATIA

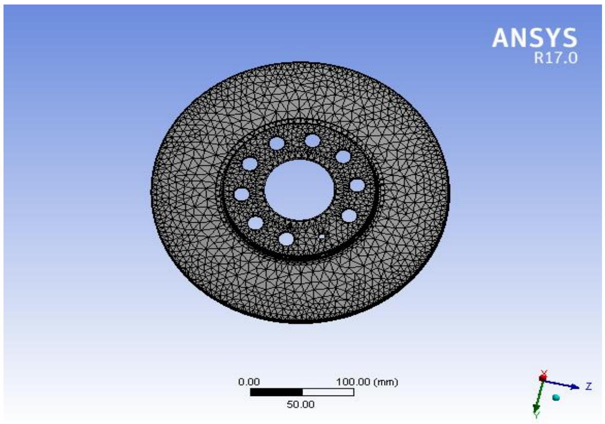

Figure 5.2 CAD Model imported in ANSYS and generate meshing

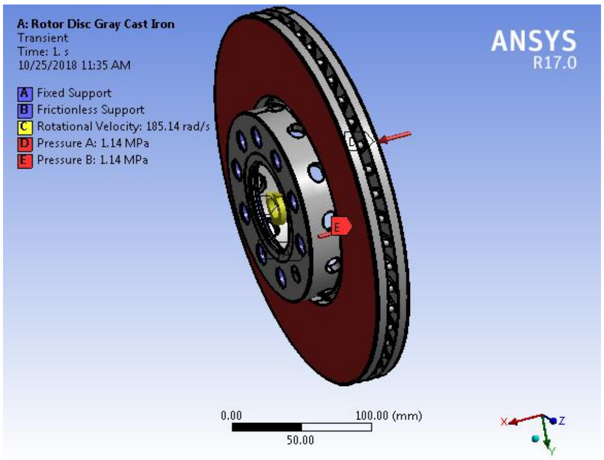

Figure 5.3 Applied boundary conditions

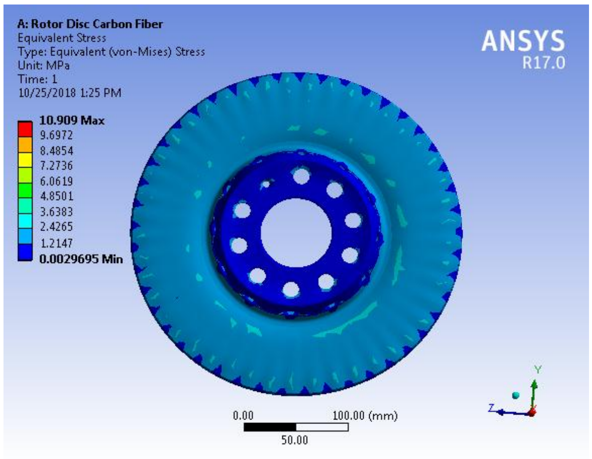

Figure 5.4 Von misses stresses in Carbon Fiber Brake Rotor

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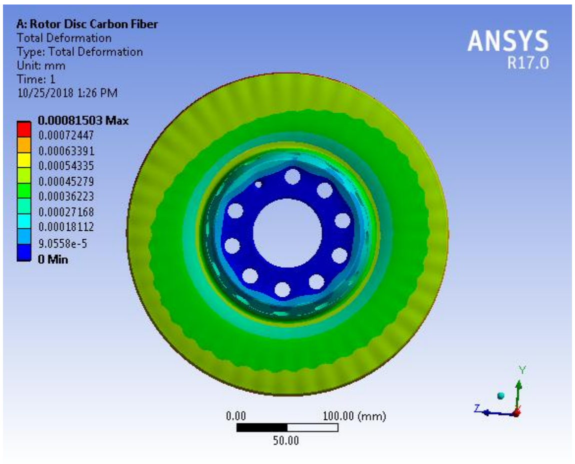

Figure 5.5 Deformation in Carbon Fiber Brake Rotor

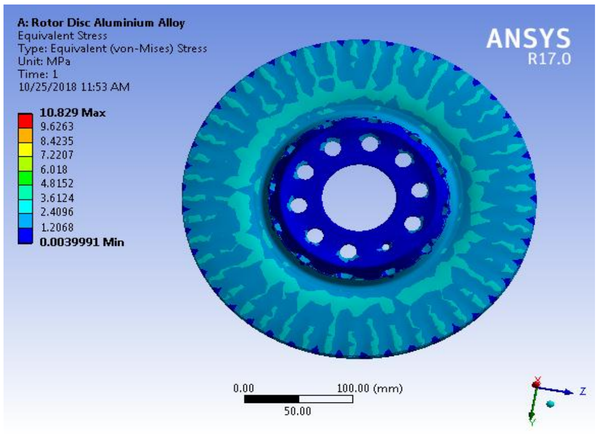

Figure 5.6 Von misses stresses in Aluminium Alloy Brake Rotor

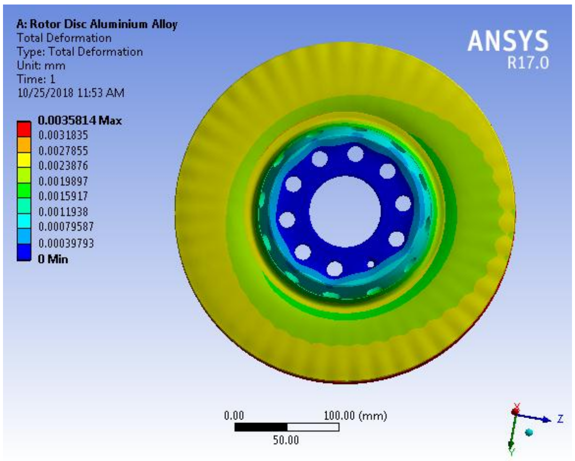

Figure 5.7 Deformation in Aluminium Alloy Brake Rotor

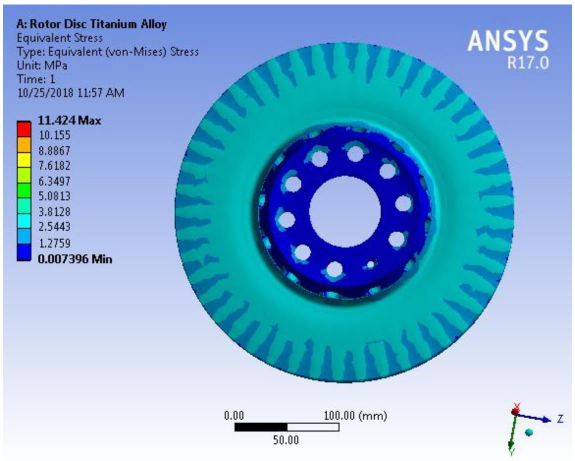

Figure 5.8 Von misses stresses in Titanium Brake Rotor

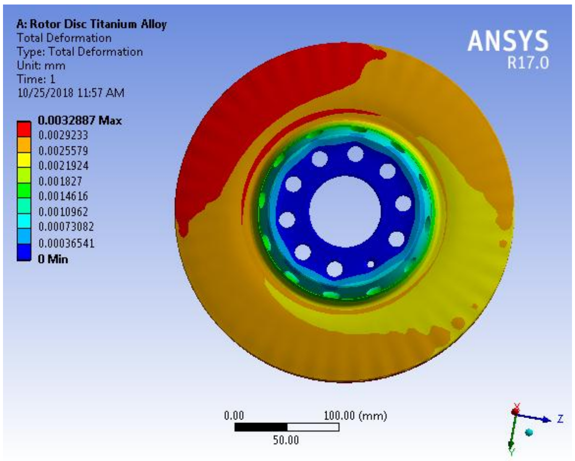

Figure 5.9 Deformation in Titanium Brake Rotor

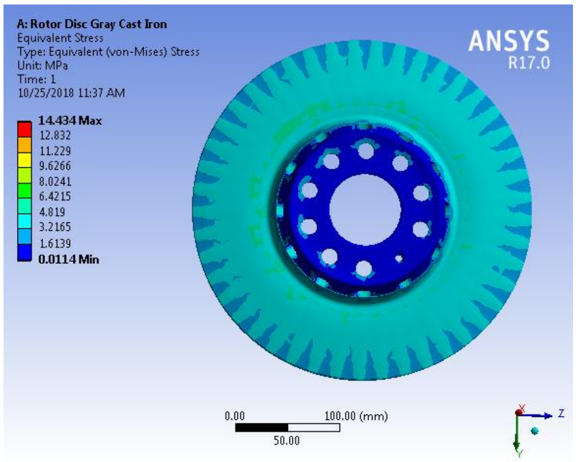

Figure 5.10 Von misses stresses in Gray Cast iron Brake Rotor

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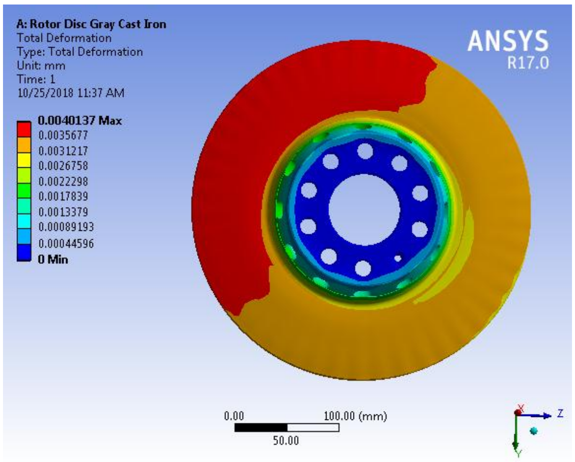

Figure 5.11 Deformation in Gray Cast Iron Brake Rotor

VI. ANALYTICAL CALCULATION

Audi A3 Car

Car Kerb weight = 1340 kg

Velocity v = 100 km/hr = 27.77 m/sec
KE =1/2 mv^2 = 1/2 x 1250 $(27.77)^2$ = 5.1 $x10^5$ Joules

Braking force (F_B) = work/ Displacement = W/s = 5.1 $x10^5$/55.2 = 9360.25 N

Now we take 60% and 40% ratio

So 60% (5616.15 N on front Two wheels) and (3744 N on rear two wheels)

For Single wheel (Front) Force = 5616.15/2 = 2808.05 N

Force by one piston = 1674/4 = 418 N

Velocity (v) = Π DN / 60 = 27.77 = Π X 0.300 X/60

N = 1767.89 say = 1768 RPM

w= 2ΠN/60 = 2 X 3.14X 1768 / 60 = **185.144** rad/sec

Piston Pressure = Force / Area

P = F /A

Area = Π / 4 x d^2= Π / 4 x $(28)^2$ = 615.75 mm^2

P_1= 702.018/615.75 = **1.14 MPa**

P = P1 + P2 = 1.14 + 1.14 = 2.28 MPa

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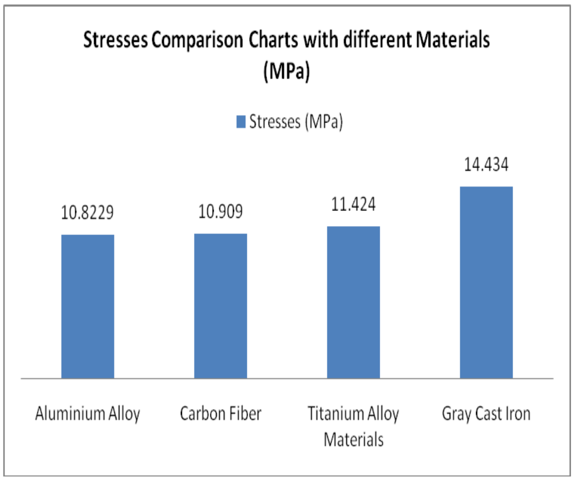

Figure 6.1 Stresses comparison Charts

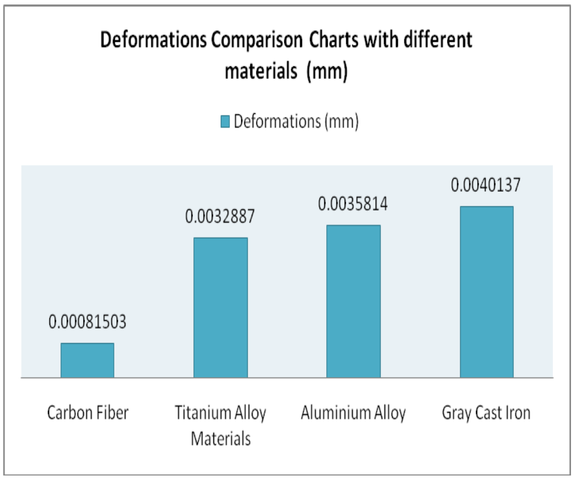

Figure 6.2 Deformations comparison charts

VII. RESULT & DISCUSSION

In above Graph its cleared that we take different four materials and seen that the maximum von misses stress value for All material like Gray Cast Iron , Titanium Alloy, Aluminium Alloy and Carbon Fiber respectively are 14.434 MPa, 11.24 MPa, 10.82 MPa and 10.909 MPa . Here we can clearly observed that Carbon Fiber has considerable value of stresses compare to other materials.

We get maximum deformation value for all material like Gray Cast Iron , Titanium Alloy, Aluminium Alloy and Carbon Fiber respectively are 0.0040mm, 0.00328mm, .003581mm and 0.000815 mm .

Here we can clearly observed that Carbon fiber has very less value of deformation compare to other materials and it is desirable under the limit. So it is safe for future design.

So we suggest Carbon Fiber for brake rotor design in future. Because it is light weight and durable material.

Carbon Fibers needs to be layered in multiple directions to be useful (somewhat like plywood). If not, all the fibers will be going in one direction and the material will be prone to splitting because there will be no strength in the cross-wise direction, just like wood veneer. If you layer carbon fiber in such as way as to have most uniform properties (a so-called "quasi-isotropic" laminate) you end up with overall properties somewhat like Aluminium . In fact, if you do this, you will end up with a laminate that's a bit heavier than Aluminum.

So, after all that, how much lighter and stiffer is it? Well, the better answer is: if you have a structure that can take advantage of the directional properties of carbon Fiber, like a bicycle wheel or frame tube, or a helicopter blade, where certain pieces of it can be aligned with the flexing or stress that the part will see, you can get *up to* about a 30% weight savings over Aluminum.

VIII. CONCLUSION & FUTURE SCOPE

7.1 Conclusion

The disc brake is a device for decelerating or stopping the rotation of a wheel. Braking is a process which converts the kinetic energy of the vehicle into mechanical energy which must be dissipated in the form of heat. This paper presents the analysis of the contact pressure distributions at the disc interfaces using a detailed 3-dimensional model of a real car disc brake. Determination of the braking force is the most crucial aspect to be considered while designing any braking system. The generated braking force should always be greater than the required braking force. The calculation of

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required clamping force helps us to decide the parameters of the disc brake rotor. Modeling and analysis o disc brake rotor is done to select the best material which is more durable. Space and assembly constraints are also an important factor while designing the rotor body. Find out the value of deformations and stresses due to cause of pressure.We take four different materials Grey Cast Iron, Aluminium Alloy, Titanium Alloy and Carbon Fiber in our resesrch. Analysis is done on these materials and conclude that Carbon Fiber shows the minimum stress and deformation values in boundary conditions. So Carbon Fiber is sujjested for future manufacturing of Disc Brake Rotor.

7.2 Future Scope

In future this work can be extended by using different composite materials and we can do thermal CFD analysis and Vibrational analysis in dick brake calliper with different boundary condition like fluid pressure temperature etc.

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