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# Structural Analysis of Disc Brake Rotor for Different Materials

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**Abstract -** *In this paper we are going to find the temperature on surface of disc brake rotor for different materials, to find the best suitable alternative material for disc brake rotor. We have performed experimentation on disc brake rotor to obtain the temperature on surface of disc rotor for five different material which are Aluminium, Aluminium-Copper Alloy, Titanium - 2, Titanium – 5 & Grey Cast Iron. The temperature on surface of disc rotor on outer periphery is obtained from the actual test setup for the disc brake rotor. This test is carried out for 5 minutes running with the desired condition & then suddenly applying the desired load. Also mathematical model is prepared to calculate the heat flux generated by theoretically. Actual weights of all materials were measured and the mechanical properties such as compressive strength, wear rate and coefficient of friction of material were compared. Then disc rotor is analyzed for temperature profile & total heat flux generated by using Ansys-17 and at final the analysis results are compared with experimental results to find out the best suitable alternative material other than Grey Cast Iron.*

***Key Words***: Disc Brake Rotor, Temperature analysis, Weight Reduction, Transient Analysis

## 1. INTRODUCTION

The brake disc is usually made of cast iron, but may in some cases be made of composites such as reinforced carbon–carbon or ceramic matrix composites. This is connected to the wheel and/or the axle. To retard the wheel, friction material in the form of brake pads, mounted on a device called a brake caliper, is forced mechanically, hydraulically, pneumatically, or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop. Discs may also be slotted, where shallow channels are machined into the disc to aid in removing dust and gas. Slotting is the preferred method in most racing environments to remove gas and water and to deglaze brake pads. Some discs are both drilled and slotted. Slotted discs are generally not used on standard vehicles because they quickly wear down brake pads; however, this removal of material is beneficial to race vehicles since it keeps the pads soft and avoids vitrification of their surfaces. As a way of avoiding thermal stress, cracking and warping, the disc is sometimes mounted in a half loose way to the hub with coarse splines. This allows the disc to expand in a controlled symmetrical way and with less unwanted heat transfer to the hub.

## 2. LITERATURE SURVEY

**M.A. Maleque**[12] have been study about the brake rotor 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 analysed and alternative solutions were evaluated among cast iron, aluminium alloy, titanium alloy, ceramics and composites. He has been considered 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 AMC 2 material and identified as an optimum material among the candidate materials for brake disc. 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.

**Faramarz Talati**[13] have been study the governing heat equations for the disk and the pad are extracted in the form of transient heat equations with heat generation that is dependant to time and space. In the derivation of the heat equations, parameters such as the duration of braking, vehicle velocity, geometries and the dimensions of the brake components, materials of the disk brake rotor and the pad and contact pressure distribution have been taken into account. The problem is solved analytically using Green's function approach. It is concluded that the heat generated due to friction between the disk and the pad should be ideally dissipated to the environment to avoid decreasing the friction coefficient between the disk and the pad and to avoid the temperature rise of various brake components and brake fluid vaporization due to excessive heating.

**Susmitha Sankatala**[3] have been study about Friction causes between disc and attached wheel to slow or stop. Brakes convert friction to heat, but if the brakes get too hot, they will cease to work because they cannot dissipate enough heat. This condition of failure is known as brake fade. Disc brakes are exposed to large thermal stresses during routine braking and extraordinary thermal stresses during hard braking. The aim of the paper is to model a disc brake used in Honda Civic. Structural and Thermal is done on the disc brake. The materials used are Stainless Steel, Cast Iron and Aluminium Alloy. 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.

## 3. PROBLEM DEFINATION

1. Compare the weight, Strength & stresses induced in Disc brake rotor for all material according to criteria minimum weight, high compressive strength & minimum induced stresses.

2. Find the best alternative possible material for disc brake rotor by comparing all experimental investigated parameters & analysed parameters.

## 4. EXPERIMENTATION

1. Grey Cast Iron (GCI)
2. Aluminium Alloy (Al)
3. Titanium Alloy (Ti-2)
4. Titanium Alloy (Ti-5)
5. Aluminium-Copper alloy (Al-Cu)

**Table-1:** Standard Properties of Material [03]

| Material | GCI | Al | Ti-2 | Ti-5 | Al-Cu |
|---|---|---|---|---|---|
| **Thermal Conductivity** $(w/mK)$ | 58 | 237 | 16.3 | 7.3 | 399 |
| **Mass Density** $(Kg/m^3)$ | 7800 | 3020 | 4510 | 4420 | 2840 |
| **Specific Heat** *(KJ/KgK)* | 460 | 910 | 540 | 570 | 390 |
| **Coefficient of Friction** $(\mu)$ | 0.4 | 1.10 | 0.32 | 0.28 | 0.29 |
| **Compressive Strength** *(Mpa)* | 1293 | 406 | 1070 | 1300 | 761 |
| **Specific Gravity** *(Kg/m³)* | 7200 | 2660 | 4420 | 4680 | 2800 |
| **Ultimate Strength** *(Mpa)* | 320 | 240 | 870 | 1020 | 515 |
| **Yield Strength** *(Mpa)* | 210 | 200 | 752 | 950 | 276 |
| **Wear Rate** $(\times 10^{-6} mm^3/N/m)$ | 2.36 | 3.25 | 8.19 | 24.6 | 2.91 |

The weight of disc rotor for all materials were recorded by actually weighing the disc materials and which were given below in table no.-2.

**Table-2:** Actual weight of disc brake rotor for different materials

| Material | Weight *(Kg)* |
|---|---|
| GCI | 4.510 |
| Al | 2.762 |
| Ti-2 | 3.200 |
| Ti-5 | 3.500 |
| Al-Cu | 2.472 |

From table no.-2, we get that the density of Grey Cast Iron is very high compared to other material from which we were observed that the GCI having the more weight other than all tested materials as observed in actual weight measurement.

## 5. TRANSIENT STRUCTURAL ANALYSIS

In transient structural analysis we have analyzed all the material for Von-Mises Stress, Max Principal Stress, Shear Stress & total Deformation of rotor in transient state. The boundary condition were considered as a fixed bolt support on all wheel hub and the pressure applied on a friction area. After analyzing the disc rotor for every material, the obtain results were shown in below.

The figure 1 to 6 shows the transient structural analysis of Grey Cast Iron material were the max principal stress induced at contraption area and value is 1.762 Mpa. The von-Mises Stress Induced at the bolting points of Disc Rotor and max value of it is 1.8585 Mpa. The total deformation of rotor is 0.001688 mm and is were observed at the outer periphery of rotor and minimum at centre of rotor.

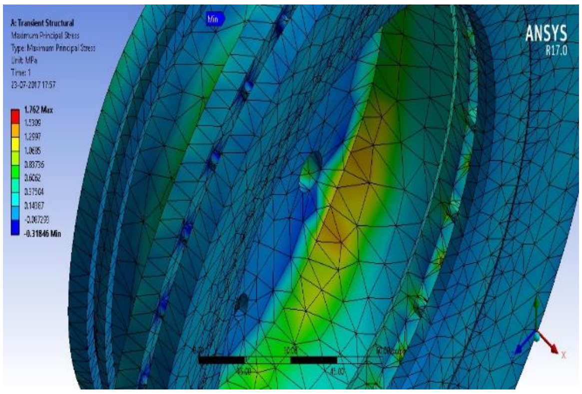

**Figure-1:** Maximum Principal Stress in GCI (Side View)

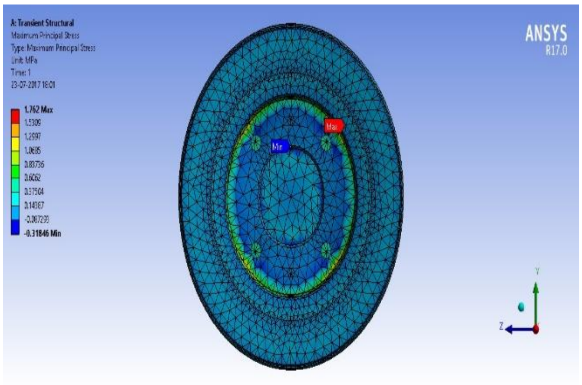

**Figure-2:** Maximum Principal Stress in GCI

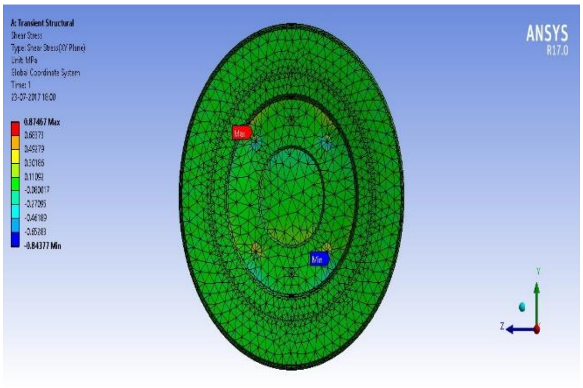

**Figure-3:** Shear Stress (XY Plane) in GCI

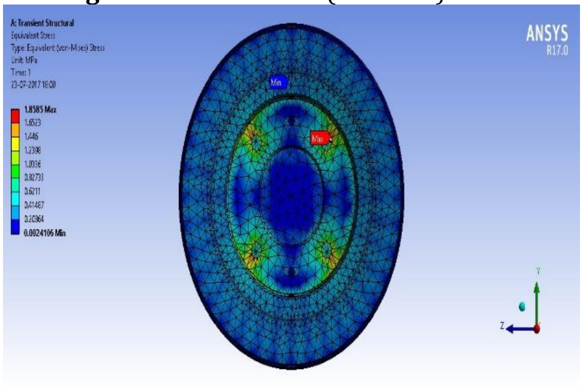

**Figure-4:** Equivalent (Von-Mises) Stress in GCI

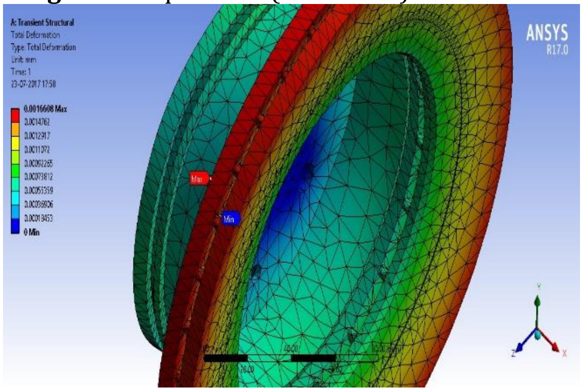

**Figure-5:** Total Deformation in GCI *(Side View)*

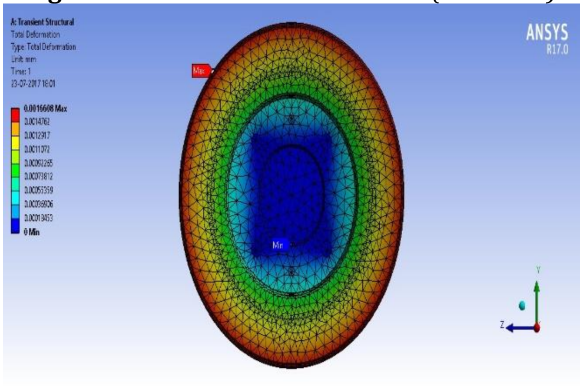

**Figure-6:** Total Deformation in GCI

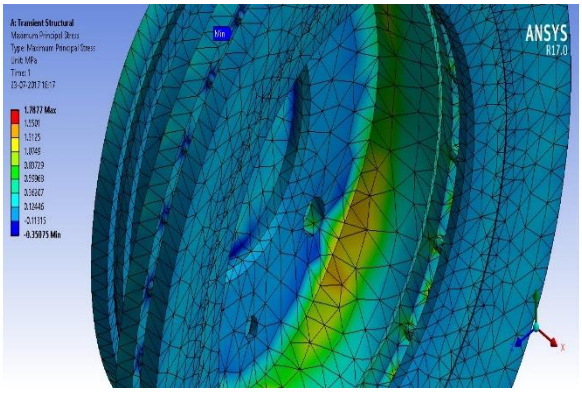

**Figure-7:** Maximum Principal Stress in Al (Side View)

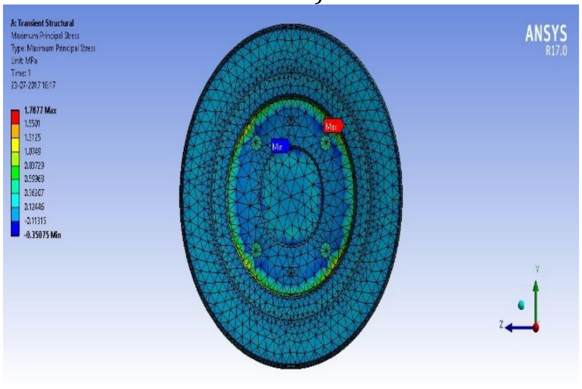

**Figure-8:** Maximum Principal Stress in Al

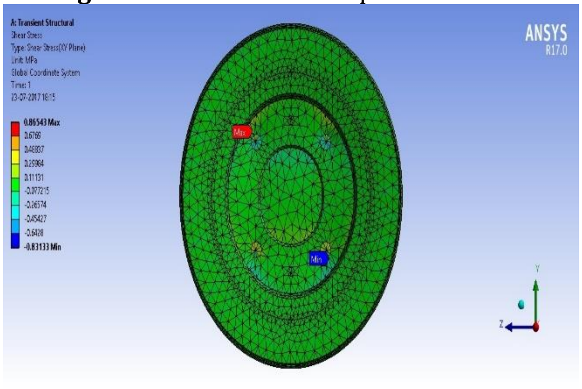

**Figure-9:** Shear Stress (XY Plane) in Al

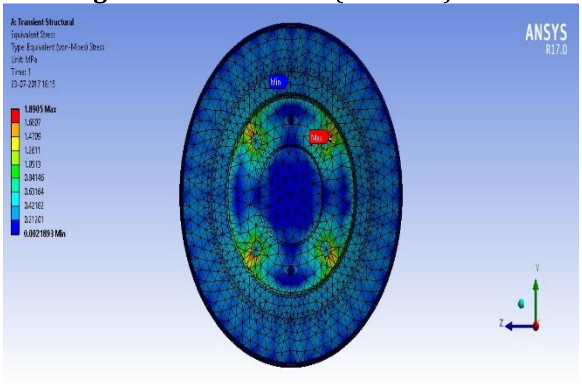

**Figure-10:** Equivalent (Von-Mises) Stress in Al

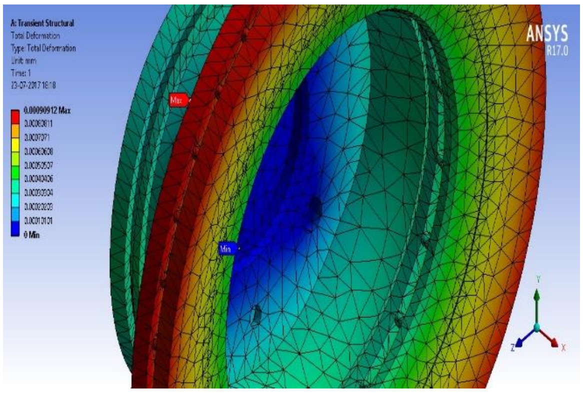

**Figure-5.11:** Total Deformation in Al *(Side View)*

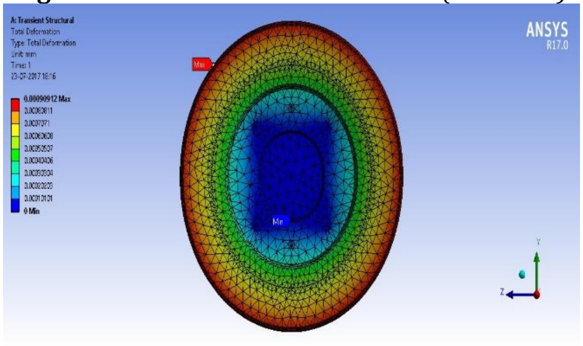

**Figure-12:** Total Deformation in Al

The figure 7 to 12 shows the transient structural analysis of Aluminium material were the max principal stress induced at contraption area and value is 1.5 Mpa. The von-Mises Stress Induced at the bolting points of Disc Rotor and max value of it is 1.054 Mpa. The total deformation of rotor is 0.0009888 mm and is were observed at the outer periphery of rotor and minimum at center of rotor.

The figure 13 to 18 shows the transient structural analysis of Al-Cu Alloy material were the max principal stress induced at contraption area and value is 1.421 Mpa. The von-Mises Stress Induced at the bolting points of Disc Rotor and max value of it is 1.0015 Mpa. The total deformation of rotor is 0.00001688 mm and is were observed at the outer periphery of rotor and minimum at center of rotor.

The figure 19 to 24 shows the transient structural analysis of Titanium-2 material were the max principal stress induced at contraption area and value is 1.8542 Mpa. The von-Mises Stress Induced at the bolting points of Disc Rotor and max value of it is 1.745 Mpa. The total deformation of rotor is 0.0000988 mm and is were observed at the outer periphery of rotor and minimum at center of rotor.

The figure 25 to 30 shows the transient structural analysis of Titanium-5 material were the max principal stress induced at contraption area and value is 1.8012 Mpa. The von-Mises Stress Induced at the bolting points of Disc Rotor and max value of it is 1.6873 Mpa. The total deformation of rotor is 0.00000158 mm and is were observed at the outer periphery of rotor and minimum at center of rotor.

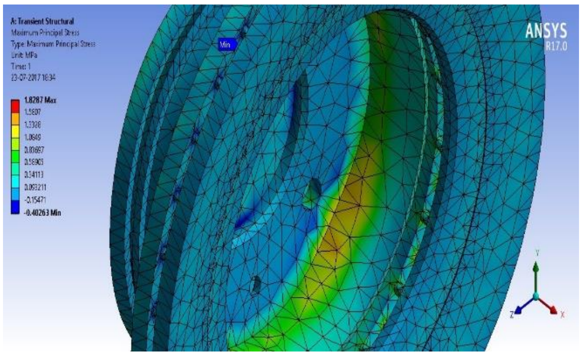

**Figure-13:** Maximum Principal Stress in Al-Cu Alloy (Side View)

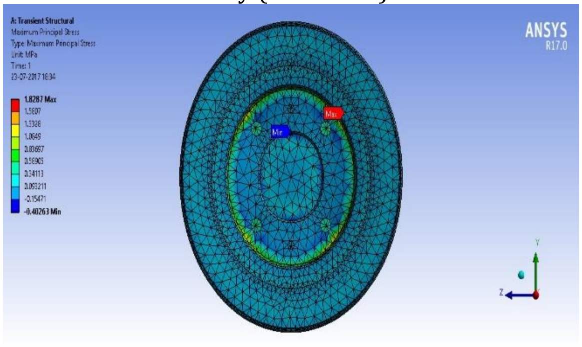

**Figure-14:** Maximum Principal Stress in Al-Cu Alloy

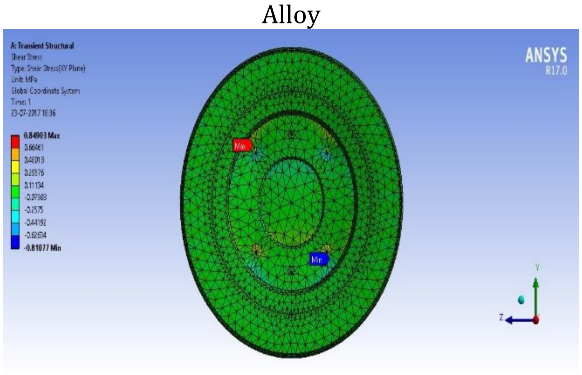

**Figure-15:** Shear Stress (XY Plane) in Al-Cu Alloy

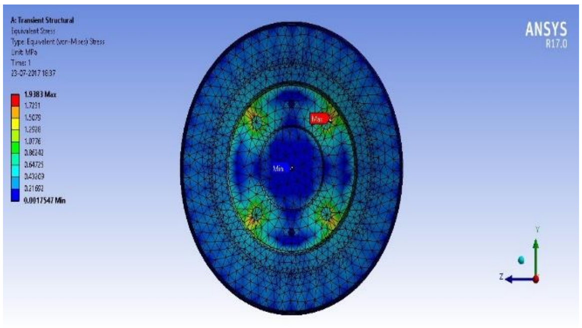

**Figure-16:** Equivalent (Von-Mises) Stress in Al-Cu Alloy

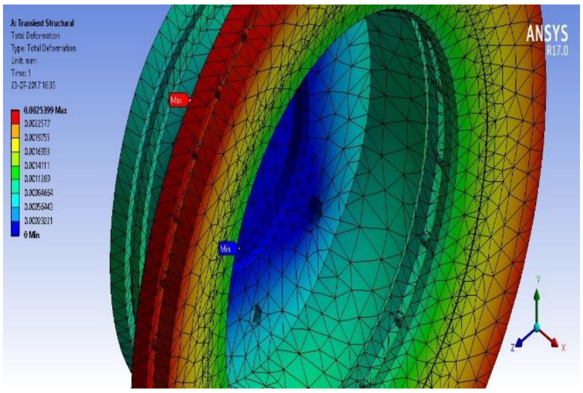

**Figure-17:** Total Deformation in Al-Cu Alloy *(Side View)*

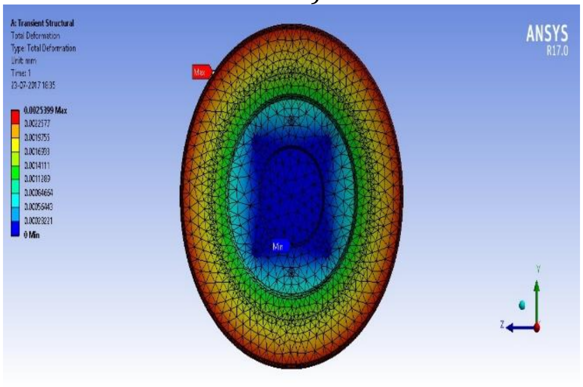

**Figure-18:** Total Deformation in Al-Cu Alloy

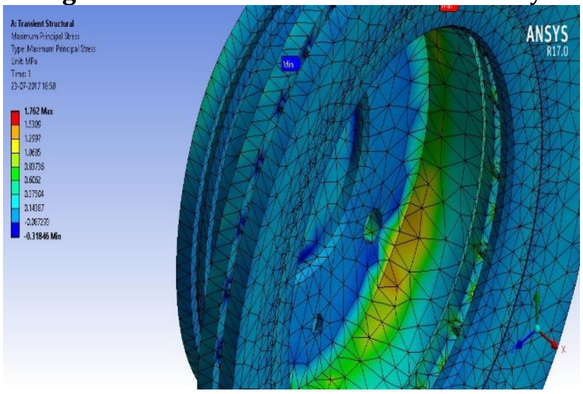

**Figure-19:** Maximum Principal Stress in Ti-2 (Side View)

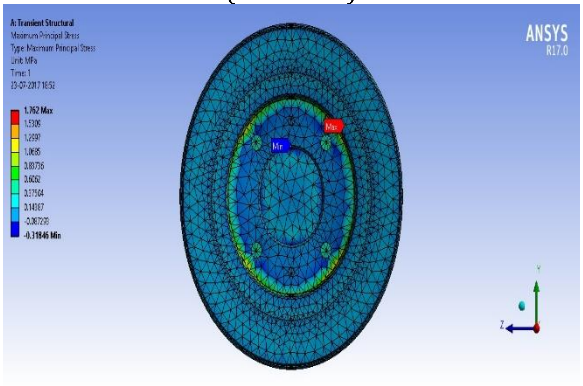

**Figure-20:** Maximum Principal Stress in Ti-2

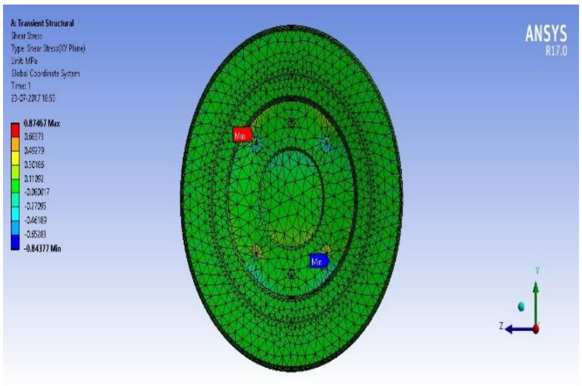

**Figure-21:** Shear Stress (XY Plane) in Ti-2

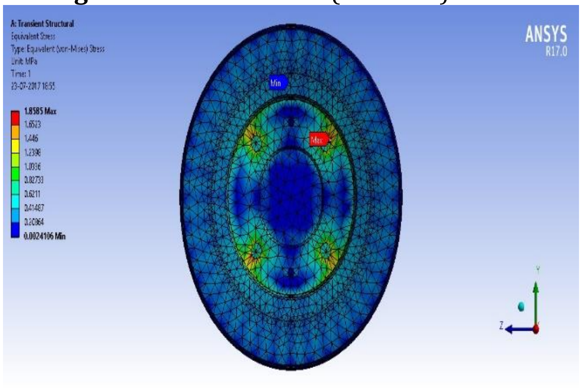

**Figure-22:** Equivalent (Von-Mises) Stress in Ti-2

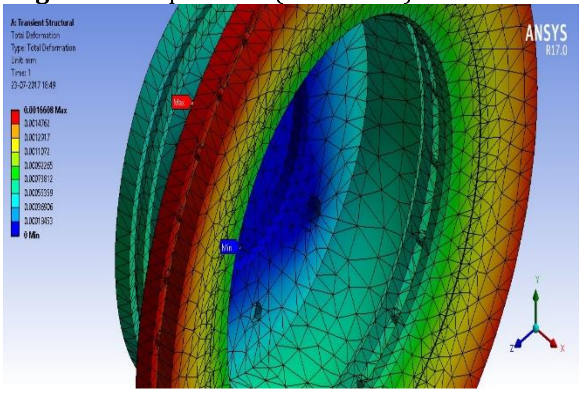

**Figure-23:** Total Deformation in Ti-2 *(Side View)*

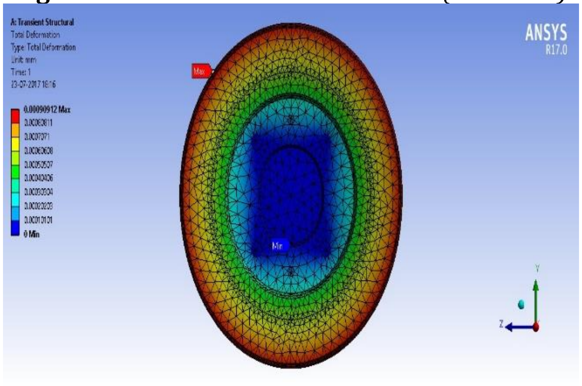

**Figure-24:** Total Deformation in Ti-2

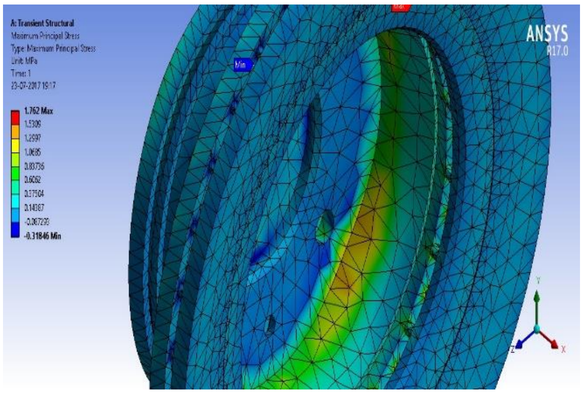

**Figure-25:** Maximum Principal Stress in Ti-5 (Side View)

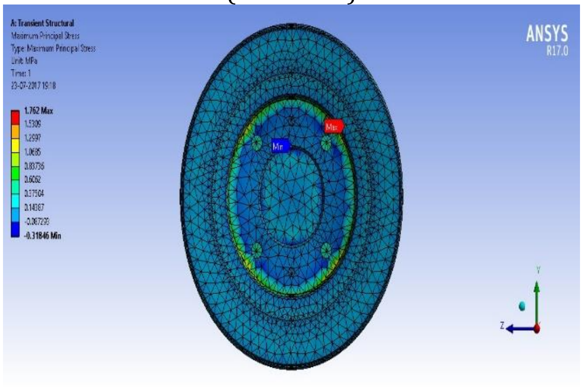

**Figure-26:** Maximum Principal Stress in Ti-5

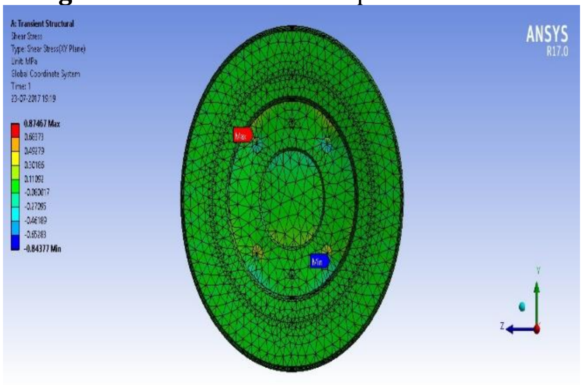

**Figure-27:** Shear Stress (XY Plane) in Ti-5

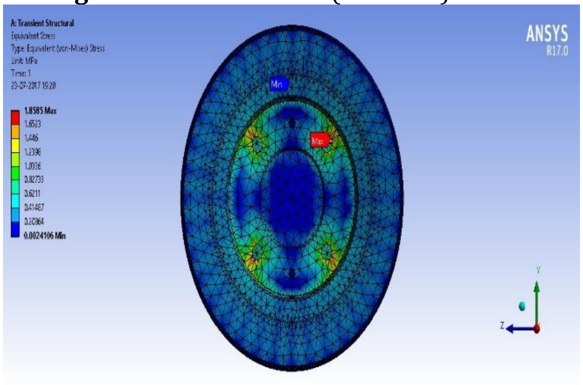

**Figure-28:** Equivalent (Von-Mises) Stress in Ti-5

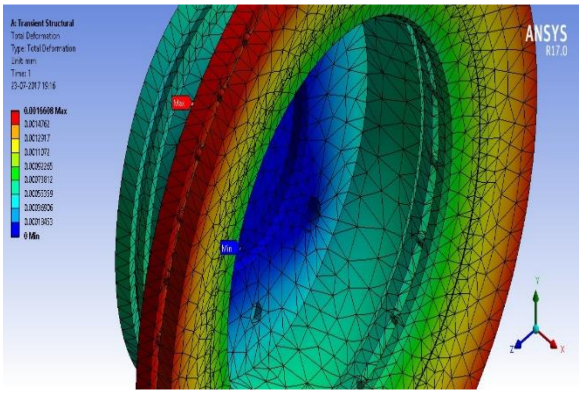

**Figure-29:** Total Deformation in Ti-5 *(Side View)*

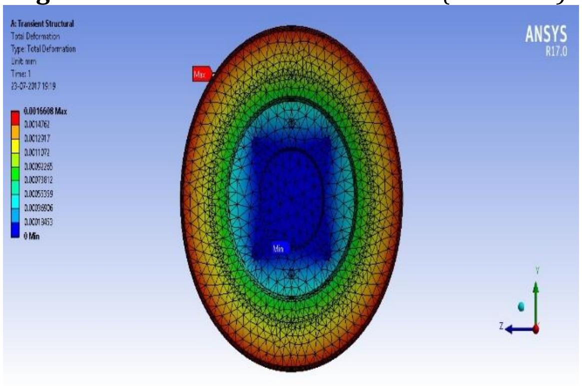

**Figure-30:** Total Deformation in Ti-5

## 6. RESULT & DISCUSSION

From all the values recorded in transient analysis, it is observe that the Maximum principal Stresses induced in Titnium-2 which is 1.8542 Mpa. The maximum von-Mises Stress induced in Titanium-2 which is 1.745 Mpa. It is observe that the lowest deformation is present in AL-Cu Alloy which is 0.00001688 mm. Also the Von-Mises stress are also less compared to other material. So from comparing all analysis it is found that the Al-Cu material is best option for Grey Cast Iron Material.

## 7. CONCLUSIONS

From transient analysis, it were observed that the Maximum Principal Stresses, Von-Mises Stresses, Shear Stress induced in Al-Cu alloy is less among all materials. Also the deformation were very small compared to Al-Cu alloy Material.

From theoretical study, it was justify that higher friction coefficient and lower density are advantageous from the technical and economical point of view for this type of application.

So from all above experimentation and analysis, it is observed that Al-Cu alloy is best suitable alternative option for grey cast iron disc brake rotor.

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