# PERFORMANCE OF C45 AS BRAKE ROTOR MATERIAL

**Saurabh V. Surashe , Ashish S. Utage**

†BE Student, ‡Professor, Department of Mechanical Engineering, MIT College of Engineering, Kothrud, Pune, Maharashtra

**Abstract**

**Braking system in the vehicle enables driver to accelerate**. As we are proceeding in 21century advancement in automobile sector are increasing gradually. The braking system of vehicle is also changed from drum brake to disc brake. The main objective of braking system in vehicle is reduce the speed of vehicle or control the motion vehicle. The kinetic energy possessed by vehicle is dissipated by braking system. In past years, in braking system we have used drum brake but, as technology increases drum brakes are replaced by disc brake. When hard brakes are applied, thermal stresses are induced in brake disc which leads to the generation of higher temperature. Hence for the better performance brake rotor material is selected on the basis of low structural stress and thermal stress . So, the main objective of this paper is to carry out the structural and thermal analysis of brake disc whose model is done on Solidworks.17 software.

**Keywords:** Brake rotor, thermal analysis, static/structural analysis, Solidworks.17, FEA (Finite Element Analysis).

## 1. Introduction

As the automobile technology goes developing drum brakes in the vehicle is replaced by disc brakes. Motion of the vehicle is retarded or stopped by brake system. Basically, brake system is a hydraulic system, consists of brake caliper, brake rotor, and brake master cylinder and the hoses which are used for brake fluid transmission. Brake system working is depended on brake fluid which gets pressurised by pressing the brake pedal. This pressurised fluid presses the piston of brake caliper which intern presses the brake rotor with the help of brake pad and hence, brake gets applied.

The most important part of brake system is brake rotor. By pressing the brake rotor by brake pad it gets heated and so, this heat dissipation from brake rotor is necessary. Due to this reason, earlier brake rotor are mostly made up of cast iron, stainless steel and carbon-carbon composite. Over heating of brake rotor during braking process leads to brake fading, brake squealing and crack formation. These effects have larger effect on brake performance.

### A. Factors affecting brake performance

Following four factors determine the brake performance of the brake system. These four factors defines how friction is responsible for the generation of heat energy and also it's dissipation.

I. **Pressure :** The pressure which is generated by brake master cylinder and piston helps in generating frictional force between the moving surfaces in contact.

II. **Coefficient of Friction :** Here two types of coefficient of friction are present, first friction between road surface and tyre and friction between brake pad and brake rotor. This both coefficient of friction plays very important role in design of brake system.

III. **Frictional contact surface :** The frictional contact surface area is area from which all heat which is generated is dissipated.

IV. **Heat :** The heat generated is the important parameter for the design of brake system. The thermal analysis of brake rotor is depended on heat flux. As we apply brakes, the kinetic energy is converted into heat energy and this heat energy increases temperature of rotor. Due to increase in temperature, air which surrounds the rotor gets trapped in brake rotor and this reduces the coefficient of friction between the rotor and brake pad. This trapping of air is called brake fading. Brake fading reduces the braking power of vehicle.

### B. Objective

The objective of the paper is to design cost effective and also the brake rotor having better cooling properties. For that we are making a model of brake rotor in Solidworks.17 and carrying out the finite elemental analysis in same software. Thus we are obtaining the values of shear stress, total deformation and temperature distribution brake rotor and checking for the factor of safety.

 **DOI : 10.18231/2454-9150.2018.1454**

## 2. Literature review

Ali Belhocine et. al. in their "Structural and thermal analysis of automotive disc brake rotor" used ventilated disc brake for analysis and stated that the temperature, tensile stress and the total deformations of the brake disc increases. High temperature generation causes crack propagation in rotor and it also causes the wear and tear of brake pad. So he carried out the structural and thermal analysis of disc brake and compared that result with those of specialized literature. In ventilated disc brake ventilation are provided for the cooling operation of vented disc brake and vented disc brake also show good temperature resistance.

Saurav Rajgadia et. al. stated in "Structural and thermal analysis of brake rotor using Solidworks and Ansys " that aluminium alloy 6262T-9 can be used as brake rotor as it has good specific heat and hence it will give good cooling. He first design model of brake rotor in Solidworks workbench and then done its analysis in Ansys R 14.5 For the design he has considered low stress material for brake rotor to get good performance in structural and thermal stress analysis.

According to Viraj Parab in their "Structural and thermal analysis of brake disc" stated that stainless steel and cast iron both can be used as brake rotor material. He carried out analysis on both the stainless steel and cast iron and found that stainless steel gives good performance in deformation point of view and cast iron gives good performance in stress analysis. So from this result we came to know that the material which have properties of both stainless steel and cast iron would be good brake rotor material.

Table 1: Properties of material

| Property | Cast iron | Stainless steel | Carbon-carbon composite |
|---|---|---|---|
| Density (kg/m$^3$) | 6800 - 7800 | 7500 | 1600–1980 |
| Poisson ratio | 0.25 | 0.30 | 0.31 |
| Young's modulus (GPa) | 125 | 190 | 95 |
| Thermal conductivity (W/m-K) | 27-46 | 26 | 40 |
| Specific Heat (J/kg-K) | 460 | 500 | 755 |
| Coefficient of friction | 0.2 | 0.22 | 0.3 |

Swapneel Kulkarni et. al. stated in their "Thermal analysis of brake disc" that the temperature rise for DB410 is much less as compared to other material so it can be used as brake rotor material as it has high thermal conductivity and has moderate specific heat capacity. It can be heat treated to increase its hardness and but it will reduce coefficient of friction. He has taken DB410, aluminum and cast iron as brake rotor material. He found that cast iron gives better result in heat dissipation but it gets easily corroded as it comes in contact of water and moisture. DB410 materials has best heat dissipation capacity and also its working time period is more i.e. its life is more . So, DB410 material can be used as brake rotor material.

## 3. Methodology

In this process we are designing the rotor, doing its analysis in software and also we are going to check its result practically by mounting on car.

### A. Design parameter

Design parameter means the values of variables we are assuming for the calculation of braking torque, heat flux or heat power.

Table 2: Values of various vehicle variables

| S. no. | Parameter | Value |
|---|---|---|
| 1. | Disc diameter | 120-170 mm |
| 2. | Disc thickness | 4.5 mm |
| 3. | COG of vehicle | 290 mm |
| 4. | Wheelbase | 1550 mm |
| 5. | Axle weight distribution | 45:55 |
| 6. | Top speed of vehicle | 100kph (28m/s) |
| 7. | Tire size | 230mm |
| 8. | Mass of vehicle | 185 kg |
| 9. | Effective rotor diameter | 147 mm |
| 10. | Deceleration | 13.74 m/s$^2$ |
| 11. | Deceleration time | 2.03 sec |

### B. Brake calculation

Front static weight = 83.25 kg
Rear static weight = 101.75 kg
Weight transfer due to braking = 290*185*1.4/1550 = 48.45 kg
Front dynamic weight = 83.25 + 48.45 = 131.7kg
Rear dynamic weight = 101.75-48.45 = 53.3kg
So,
Weight on front one tire = 131.7/2 = 65.85kg
Braking torque on front tire= 65.38*2*9.81*230/2 =147.516 N-m
Now,
Kinetic energy absorbed by disc = 90% of total kinetic energy
= 0.9*0.5*65.85*28*28= 23066.064 J
Braking power = kinetic energy/time
=23066.064/2.037= 11323.54 Watt
Heat flux = braking power/area = 11323.54/0.011
= 1029413.308 Watt/m$^2$

### C. Material selection

For brake rotor material is selected on the basis of its convective heat transfer coefficient, heat dissipation capacity, its hardness and good working performance in higher temperature values. Considering all this variables we have selected C45 as the brake rotor material.

Table 3: Chemical composition of C45

| S. no. | Material | Percentage |
|---|---|---|
| 1. | Carbon | 0.43-0.50 |

 DOI : 10.18231/2454-9150.2018.1454

| | | |
|---|---|---|
| 2. | Silicon | 0.17-0.40 |
| 3. | Manganese | 0.50-0.80 |
| 4. | Phosphorus | 0.040 |
| 5. | Sulphur | 0.050 |
| 6. | Chromium | 0.40 |
| 7. | Nickel | 0.40 |

Table 4: Properties of C45

| S. no. | Property | Value |
|---|---|---|
| 1. | Elastic modulus | 2.050000031e+11 (N/m²) |
| 2. | Poisson ratio | 0.29 |
| 3. | Shear modulus | 7.2e+010 (N/m²) |
| 4. | Mass density | 7850 (kg/m3) |
| 5. | Tensile strength | 660000000 (N/m²) |
| 6. | Yield strength | 570000000 (N/m²) |
| 7. | Thermal expansion coe. | 1.2e-005 |
| 8. | Thermal conductivity | 14 (1/K) |
| 9. | Specific heat | 470 (J/kg-K) |

### D. Modeling of Brake rotor

The general model of rotor is designed in Solidworks.17 Now for the analysis of rotor following assumptions are taken into consideration.

1. While doing the anlysis, for calculation we have considered weight distribution of vehicle as 45:55 (front : rear ).
2. In this analysis we haven't calculated fatigue results and during whole analysis pure thermal conditions are considered.
3. For thermal analysis transient air conditions are into account.
4. The kinetic energy lost through disc brake and no any other heat loss through tyre. Deceleration is uniform.
5. The thermal conductivity of rotor material is constant throughout.
6. The specific heat of rotor material does not varies with the time interval.

After the calculation, braking torque is taken as input to the structural analysis of the brake rotor. And for the thermal analysis, heat flux or heat power is taken as input along with the ambient temperature.

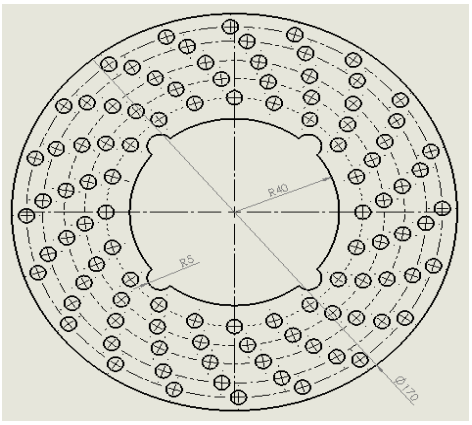

Fig. 1: Diamensional model of brake rotor

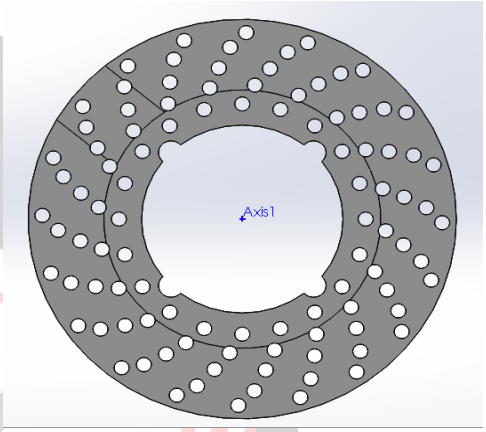


Fig. 2: Model in Solidworks.17

## Results

### FEA Analysis

### A. Structural analysis

Structural analysis means stress concentration, strain concentration and total displacement of brake rotor after the application of braking torque.

#### 1. Stress analysis

It shows the stress generated on brake rotor. The dark blue part shows least stress and it goes on increasing as it turns into red.

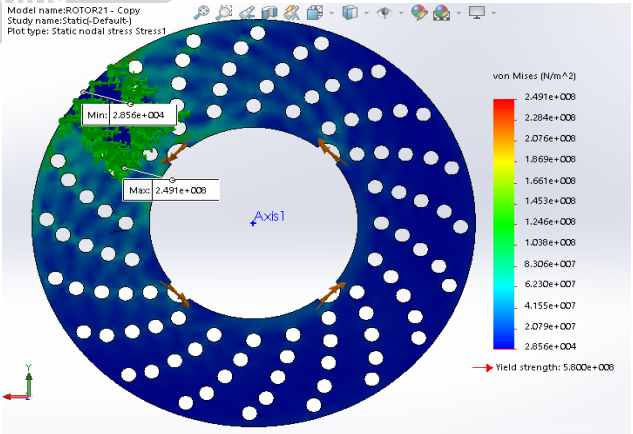


Fig.3: Stress analysis

 DOI : 10.18231/2454-9150.2018.1454

### 2. Displacement analysis

It gives the value of deformation occurring in the brake rotor due to this high stress generation. Its color distribution is same as that of above graph.

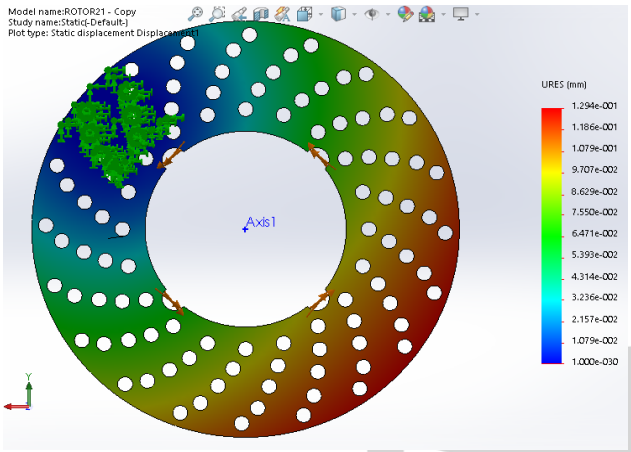


Fig.4: Displacement analysis

### 3. Strain analysis

This graph shows the strain generated due to deformation occurred in the brake rotor. Blue color in graph shows least strain and red shows highest.

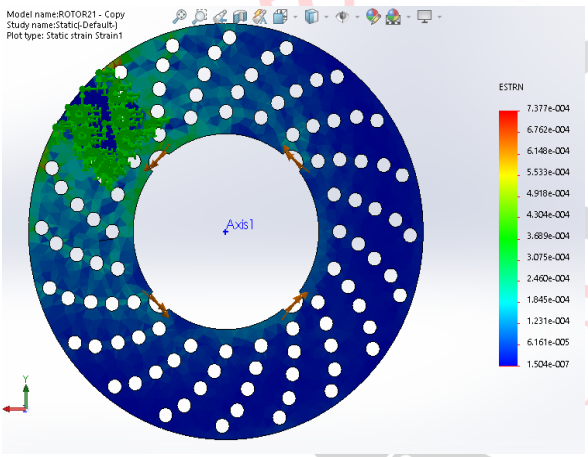


Fig.5: Strain analysis

### 4. Factor of safety

It is the main graph of all the above. It displays us that the design is safe in all parameter or not. If factor of safety is greater than 1 means it is safe and if it is less than 1 then we have to redesign our model.

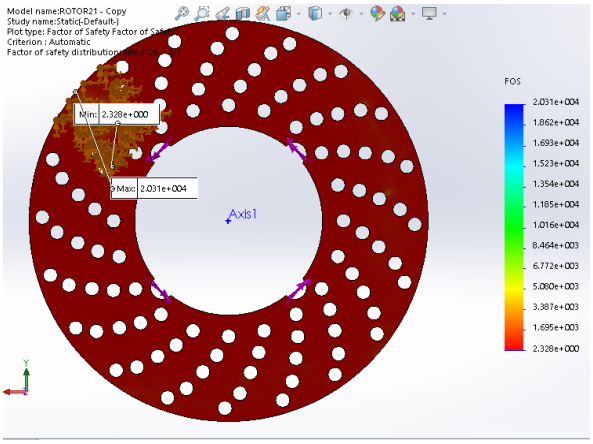


Fig.6: Factor of Safety graph

### B. Thermal analysis

Thermal analysis gives us the maximum temperature rise in brake rotor. And on the basis of this value we decide that our rotor material would sustain that temperature rise or not, means this tells us the approximate working temperature range of rotor. In this graph also blue color means least temperature rise and red means highest temperature rise.

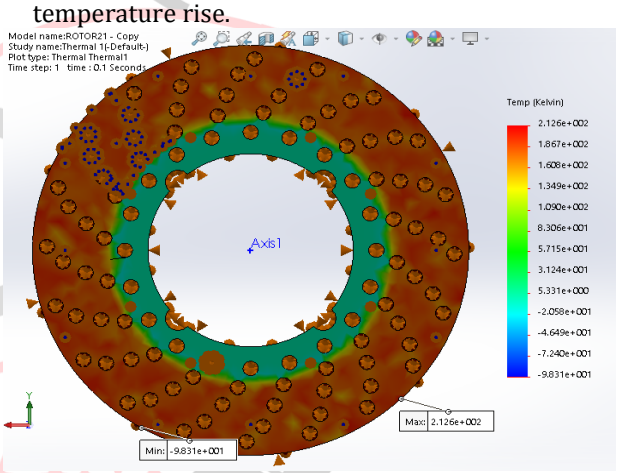


Fig.7: Rise in temperature of rotor

## Conclusions

From the above results of structural analysis as we are getting factor of safety of 2.3, so we can say that our brake rotor is safe in stress concentration. And from the result of the thermal analysis as the temperature rise is not very much and it is in the limit that in can cool down easily so, we can say that it is safe in thermal analysis. Thoroughly we can say that C45 can be used as brake rotor material for vehicles.

## References

1. Ali Belhocine et. al. (2014) Structural and thermal analysis of automotive brake rotor*Archive of Mechanical Engineering* Volume 61

2. Rakesh Jaiswal et. al. (2016) Structural and thermal analysis of disc brake using Solidworks and Ansys. *International Journal of Mechanical Engineering and Technology (IJMET)*Volume 7, Issue 1, pp 67-77, Article ID: IJMET_07_01_008.

3. Sumeet Satope et. al. (2017) Thermal analysis of disc brake. *IJIRST –International Journal for Innovative Research in Science & Technology* Volume 3, Issue 12, ISSN (online): 2349-6010

4. Viraj Parab et. al. (2014) Structural and thermal analysis of brake disc. *IJEDR* Volume 2, Issue 2, May 2014 | ISSN: 2321-9939.

5. Swapnil D. Kulkarni et. al. (2013) Thermal analysis of brake disc. *IJRET International Journal for Research in Engineering and Technology* ISSN: 2319-1163, ISSN: 2321-7308.

6. Viraj Parab et. al. (2013) Structural and Thermal Analysis of Rotor Disc of Disc Brake. *International Journal of Innovative Research in Science, Engineering and Technology*(An ISO 3297: 2007 Certified Organization) Vol. 2, Issue 12.