

# Disk Brake Designing for Go-Kart

Rajat S Panday<sup>1</sup>, Siddharth Mohanty<sup>2</sup>, Karan Bharti<sup>3</sup>, Aviral Srivastava<sup>4</sup>

B. Tech, School of Mechanical Engineering, KIIT University, Orissa, India<sup>1,2,3,4</sup>

**ABSTRACT:** A disc brake is a wheel brake which slows rotation of the wheel by the friction caused by pushing brake pads against a brake disc with a set of calipers. This paper deals with the design analysis of the brake systems of a Go kart . We have extensively designed and carried out the design analysis regarding separate parameters of the disc brake system involved in the car. For the later stages, we have optimized the working of the disc brake by optimizing the parameters in question and then did a comparative study of the 2 designs analyzed.

**KEYWORDS:** Go-Kart ,Caliper ,

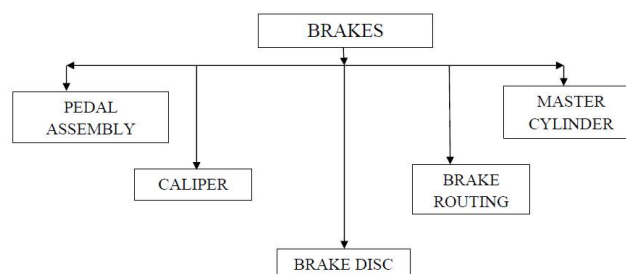
## I. INTRODUCTION

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 stop 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. Brakes convert motion to heat, and if the brakes get too hot, they become less effective, a phenomenon known as brake fade. The brake disc is the disc component of a disc brake against which the brake pads are applied. The material is typically grey iron, a form of cast iron. The design of the disc varies somewhat. Some are simply solid, but others are hollowed out with fins or vanes joining together the disc's two contact surfaces (usually included as part of a casting process). The weight and power of the vehicle determines the need for ventilated discs. The "ventilated" disc design helps to dissipate the generated heat and is commonly used on the more-heavily-loaded front disc.

### A. Objective

The main objective of the brake system is to reduce the speed of the car and stop it effectively within a particular distance and also control the car at high speeds. Brakes must be at its optimum best in order to provide smooth riding and excellent maneuverability. The car must accelerate at a minimum speed of 40 kmph and at a specified location, must stop in such a way that all REAR wheels lock simultaneously.

The target the design team had in mind was to fabricate components in such a way that the boundaries of innovation are pushed. Maximum weight reduction and easy serviceability aspects were the keynotes of the design team.



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

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 4, April 2017

## II. BRAKE DISC

The rotating disc attached to the wheel and caliper is the most important component of hydraulically operated disc braking system .

Design factors to be considered for brake disc include:

- Brake disc diameter
- Brake disc material
- Weight of brake disc
- Thickness of brake disc
- Thermal analysis

### A. BRAKE DISC DIAMETER

#### Methodology

The following steps were implemented in designing the discbrake system for the given race-car:

Specifications relevant to the brake system design on the car were collected.

#### Weight

Go kart :115 kg

Driver: 65kg

Total weight (w): 180 kg

Deceleration: 0.85g

Static rear weight(wr): 108.5kg

Static front weight(wf): 71.5kg

Tire diameter:127 mm

Coefficient of friction between ground and tire: 0.85

Coefficient of friction between tire and rotor:

Depends on the material of the rotor and pad which was 0.45

Wheel base(b): 1193.8mm

Height of centre of gravity(h): 152.4mm

#### Actual weight transfer:

- Weight transfer (wt):  $(w * a * h) / b = 195.45 \text{ N}$
- Dynamic front weight:  $wf + wt = 910.45 \text{ N}$
- Dynamic rear weight:  $wr - wt = 884.55 \text{ N}$

**Master cylinder bore diameter (am): 10mm**

**Calliper bore diameter (dc): 25.4mm**

**No. of pistons: 2 rear and 2 front**

**Pad width: 25.4 mm**

#### Some parameters had to be assumed:

- Force on brake pedal: 40kg or 400N
- Pedal ratio: 5:1

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

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 4, April 2017

The following parameters were calculated using the relevant equations:

- Master cylinder bore area:  $(3.14 * am^2)/4 = 78.5mm^2$
- Caliper bore area:  $(3.14 * dc^2)/4 = 506.45mm^2$
- Force output by pedal: force on pedal \* pedal ratio : 2000N

**Force on master cylinder= 2000 N**

**Operating Pressure:** Force on rear master cylinder / Master cylinder bore area : 25.477 N/mm<sup>2</sup>

**Clamping force:** Operating pressure \* caliper area \* no. of pistons \* coefficient of friction between rotor and pad = 5806.4 N

**Braking Torque:** (Dynamic rear weight) \* 9.81 \* (tire diameter/2) \* coefficient of friction between road and tire = 545801.6 Nmm

**Effective rotor diameter:**  $2 * (\text{Braking torque} / \text{rear clamping force}) = 189 \text{ mm}$

**Total rotor diameter:** effective rear diameter + pad width + 1mm clearance = 190 mm

**Braking force: total weight \* deceleration \* 9.81 = 9005.58 N**

**Stopping distance assuming test speed of 40kph =  $(v^2) / (2ag) = 7.40 \text{ m}$**

**Stopping Time  $t = -(u/a) = 1.33s$**

### Energy

Axle weight distribution 30% on each side ( $\gamma$ )=0.3

Percentage of kinetic energy that disc absorbs (90%)  $k=0.9$

$$\begin{aligned} \text{Total Kinetic Energy } ke &= 1/2 (m * v^2) * k * \gamma \\ &= 2999.40 \text{ j} \end{aligned}$$

The brake system exists to convert the energy of vehicle in motion into thermal energy

**Total Breaking Power  $P_b = ke/t = 2255.18 \text{ W}$**

**Total Heat Flux =  $P_b / A = 84463.96 \text{ W/m}^2$**

where  $A = .0267 \text{ m}^2$

It was seen that a brake disc of diameter 190 mm will be sufficient for transmission of the braking torque and bring the vehicle to a halt.

### B. Brake Disc Material

Brake disc material selected was Stainless Steel 420. Owing to its light weight, good thermal properties and hardness this material was selected. Another important parameter for selecting this material is the fact that the rule specified in the rule book stating that the hardness of the fabricated brake disc should be above 50 HRC.

***Hardness of at least one finished brake disc has to be tested by professional with proper proof (certificate). The minimum required Hardness is 50 HRC.***

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

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 4, April 2017

### C. Weight Of Brake Disc

Weight of the brake disc rotor was found to be 475 grams, which was found to be lighter than a contemporary OEM brake disc and also enabling better heat dissipating characteristics. In order to provide clearance for caliper and to improve surface area in contact with brake pad, brake disc diameter was fixed at 190mm.

### D. Thickness Of Brake Disc

Brake disc thickness decided was 3.5 mm. Thickness was primarily decided to provide strength to brake disc. By doing Finite Element Analysis (FEA), the thickness decided was found to hold good even for extreme conditions. As Pulsar 220's rear caliper was selected, the thickness of brake disc that can be used ranges from 3.8mm to 4.9mm. We have selected 3.5 mm as rotor diameter because it lies in intermediate range (i.e.) between 3.8 and 4.9mm.

### E. ANALYSIS

By keeping the bolts as fixed and by applying clamping pressure as **0.2MPa** on the surface of brake disc, the total deformation obtained is **0.000005249 m**. The disc can withstand a **maximum stress of 188.08 MPa** for the same loading conditions as above. Thus the brake disc designed has a **factor of safety of 2.81**.

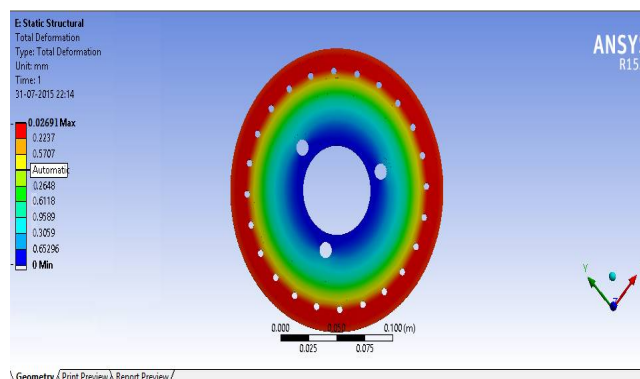


Figure 1 total Deformation

When thermally tested , total temperature rise came out to be about 120 degree centigrade, which won't initiate brake fading

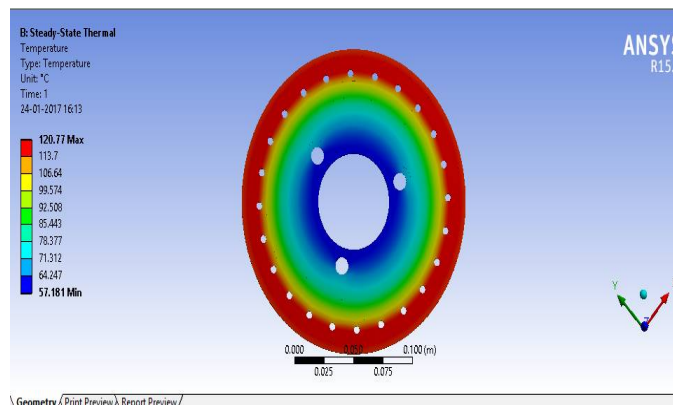


Figure 2 Thermal Analysis

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

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 4, April 2017

## III. MATERIAL COMPARISON

### Classification:

Based on metallurgical aspects and carbon content, stainless steel can be classified as follows:

- Austenitic stainless steel
- Martensic stainless steel
- Ferritic stainless steel

### Austenitic stainless steel:

E.g. SS 201, SS 202, SS 316.

It is another form of stainless steel whose carbon content is below 0.15%. Austenitic steel is non-magnetic and non hardenable. Annealing process (stress relieving) process can be done after cold working. Their hot hardness characteristics are the best among the stainless steels. It is also useful for shock resistant applications. In this form of steel, nickel content is lower and chromium content is higher. (Almost 23%)

### Martensic stainless steel:

E.g. SS 420, SS 401, SS 440A.

Martensic stainless steel is one of the many forms of stainless steel whose carbon content is greater than 0.15%. It also consists of chromium, molybdenum and nickel. It is useful for high strength and high wear applications. It is magnetic and hardenable.

### Heat treatment:

It generally involves heating this form of steel to elevated temperatures and then doing air or oil cooling.

After hot working, martensite tends to become brittle and to prevent this from happening, tempering should be done at 3500C.

Advantage of heat treatment for martensite:

Before heat treatment, the grains of martensite are needle shaped. Hence steel becomes sharp and brittle. After heat treatment the grains become more ductile and sharpness gets reduced. Owing to this kind of treatment, it renders the steel to be tough enough to withstand wear and shock loads.

Hardness:

Annealing: 85 – 100 HRB

Heat treatment: 20 – 60 HRC

### Ferritic stainless steel:

E.g. SS 430

It is another form of stainless steel whose carbon content is below 0.15%. Ferritic steel is also magnetic and non hardenable. Annealing process (stress relieving) process can be done after cold working. It is useful for corrosion applications. In this form of steel, nickel content is lower and chromium content is higher.

Hardness:

Annealing: 90 – 95 HRB

### Hot working:

If working temperature is greater than half of the welding temperature, then it becomes hot working.

If  $T > T_0$ , then it becomes hot working.

### Cold working:

If working temperature is lower than half of the welding temperature then it becomes cold working.

If  $T < T_0$ , then it becomes cold working.

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

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 4, April 2017

Hot working process is done in order to restructure the grain size, and improve the hardness at room and elevated temperatures.

**Table-1: Effect of alloyment of steel**

Properties	SS 420
Carbon content %	0.15 max
Chromium content %	12 to 14 max
Manganese content %	1.0 max
Silicon Content %	1.0 max
Yield strength (Annealed) (MPa)	220.63
HRC (Annealing)	88 B max
Hardness (Heat treated)	88 B to 55 C
Yield strength (MPa) (Heat treated)	276 to 1344
Magnetic	Yes

**Table-2: Mechanical Properties of SS 420**

Grade	SS 420
Tensile strength(MPa)	480
Yield strength (MPa)	275
Elongation %	16
Rockwell hardness	HRC 45
Brinell hardness	-
Density (kg/m <sup>3</sup> )	7800
Elastic modulus(GPa)	200
Thermal conductivity (W/m.K)	28.7
Specific heat (0-100oc) (J/kg.K)	460

## IV. MANUFACTURING PROCESS

### Laser cutting:

Laser cutting is a technology that uses a laser to cut materials, and is typically used for industrial manufacturing applications.

The laser machine uses stimulation and amplification techniques to convert electrical energy into a high-density beam of light. Stimulation occurs as the electrons are excited by an external source, usually a flash lamp or electrical arc.

Advantages of laser cutting:

- Any profile can be easily machined.
- Machining time is lower compared to other conventional manufacturing processes.
- Accuracy level of component machined is of order of microns.

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

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 4, April 2017

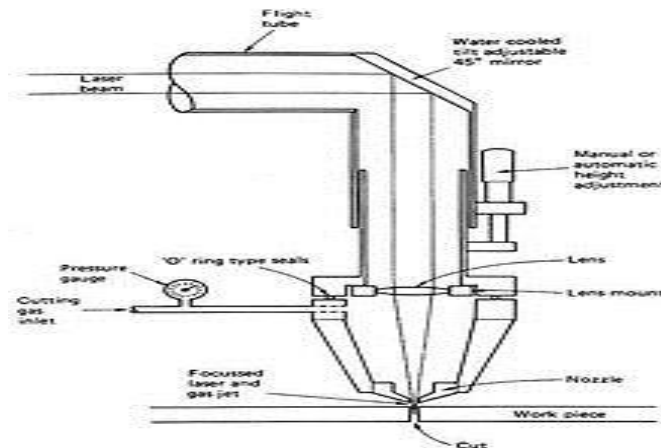


Figure 3 Laser Cutting Process

### Process involved in hardening of brake disc:

#### Stress relieving:

It is used for removing residual stresses during heavy machining or cold working processes. It is done at 550 degree Celsius for about 2 hours. It is done at temperatures below lower critical line of iron-iron carbon equilibrium diagram.

#### Tempering:

After hardening of brake disc for about 980 degree Celsius for about 2 hours followed by oil quenching, tempering is done. It involves heating the specimen to a high temperature below critical temperature and cooling it. This procedure is repeated for different cycles at slightly varying temperatures until desired properties of toughness and hardness are obtained.

### 2.11 Surface grinding

Surface grinding process was employed in order to reduce the thickness of the disc from 6mm to 4.4 mm. By doing surface grinding process, the disc was not only reduced to requisite thickness but also gives accurate surface finish of the order of 2 microns.

### 2.12 Procedure involved in selection of brake disc

Step 1: Our first step in design was in fixing the PCD of brake disc and the outer diameter of the brake disc.

Step 2: Once the profile of the brake disc was decided, material selection was considered.

Step 3: With the help of our literatures, SS 420 was finalized as our disc material. It was done owing to the following reasons:

- Hardness
- Corrosion resistance
- Thermal dissipation

Step 4: For improving hardness and toughness of brake disc, hardening process was employed. Such a process also helps in increasing the life of brake disc.

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

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 4, April 2017



Figure 4 Final Disc prepared for go-kart

## V. CONCLUSION

Disc was designed and the objective of light weight and good mechanical and thermal strength was achieved .

## REFERENCES

- [1] Ameer Fareed Basha Shaik, Ch.Lakshmi Srinivas, "Structural and Thermal Analysis of Disc Brake With and Without Cross drilled Rotor of Race Car", International Journal of Advanced Engineering Research and Studies, Vol.1, PP 39-43, 2012.
- [2] S. Sarip, "Design Development of Lightweight Disc Brake for Regenerative Braking and Finite Element Analysis", International Journal of Applied Physics and Mathematics, Vol. 3, PP 52-58, 2013.
- [3] Guru Murthy Nathil, T N Charyulu, "Coupled Structural/ Thermal Analysis of Disc Brake" IJRET, Vol.2, PP 539-553, 2012.
- [4] V. Chengal Reddy, M. Gunasekhar Reddy, "Modeling and Analysis of FSAE Car Disc Brake Using FEM" International Journal of Emerging Technology and Advanced Engineering, Vol.3, PP 383-389, 2013.
- [5] Michal Kuciej, Piotr Grzes, "The Comparable Analysis of Temperature Distributions Assessment in Disc Brake Obtained Using Analytical Method and FE Model", Journal of KONES Powertrain and Transport, Vol.18, PP 236-250, 2011.
- [6] Antti Papinniemi, Joseph C.S. Lai, "Disc Brake Squeal, Progress And Challenges" ICSV14, Australia, PP 1-8, 2007.
- [7] F.Talati, S.Jalalifar, "Investigation of heat transfer phenomenon in a ventilated disk brake rotor with straight radial vanes" journal of applied science Vol.8 PP 3583-3592, 2008.
- [8] Ali Belhocine, Mostefa bouchetara, "Thermal behavior of dry contacts in the brake discs" international journal of automotive engineering, Vol.3, PP 9-17, 2011.
- [9] Limpert Rudolf, "Brake Design and Safety", Society of Automotive Engineers. Warrandale, Inc, Second Edition, USA, PP 11-157, 1992.
- [10] Catalin Spulber, Stefan Voloaca, "Aspects regarding the disc brake's thermal stress simulation by using Infrared Thermography" International Conference on Optimization of the Robots and Manipulators Romania, ISBN 978, 26-2011.
- [11] Dr.Mushtaq Ismael Hasan, "Influence of Wall Axial Heat Conduction on The Forced Convection Heat Transfer In Rectangular Channels" Basrah Journal for Engineering Science Vol.1, PP 31-43, 2011.
- [12] G. Babukanth, M.Vimla Teja, "Transient Analysis of Disk Brake by using ANSYS Software" International Journal of Mechanical and Industrial Engineering, Vol-2, PP 21-25, 2012.