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Design and Thermal analysis of Disc Brake

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Abstract - : *Brake is a mechanical device which is used for slowing or stopping of motion. This paper present the method to design disc brakes for car and thermal analysis of rotor. The objective is to find out dimensions of rotor for given requirement and analyzing the results on ANSYS workbench. In this temperature distribution on rotor during working condition is observed.*

Key Words: **Brake, Thermal analysis, Rotor, Temperature distribution.**

1. INTRODUCTION

The 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 callipers. 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 or the axle. To stop the wheel, friction material in the form of brake pads, mounted on a device called a brake calliper, 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. Disc-style brakes development and use began in England in the 1890s

Swapnil R. Abhang, D. P. Bhaskar, in this paper carbon ceramic matrix disc brake material is used for calculating normal force, shear force and piston force. Thermal analysis and Modal analysis is done to calculate the deflection and Heat flux, Temperature of disc brake model.

Viraj Parab, Kunal Naik, Prof A. D. Dhale, the aim of the project is to design, model a disc. Modelling is done using catia. Structural and Thermal analysis is to be done on the disc brakes using three materials Stainless Steel and Cast iron & carbon composite.

K. Sowjanya, S. Suresh, this paper deals with the analysis of Disc Brake. Disc brake is usually made of Cast iron, so it is being selected for investigating the effect of strength variations on the predicted stress distributions. The results are compared with existing disc rotor.

Swapnil R Bhaskar D. P, in this paper carbon ceramic matrix disc brake material use for calculating piston force, normal force and shear force. And also calculating the brake distance of disc brake. The disc brake two wheelers model using in ANSYS and done the Thermal analysis and Modal analysis also calculate the Heat flux, Temperature distribution of disc brake model.

2. DESIGN CONSIDERATIONS AND CALCULATION

To calculate dimensions of brakes, we need to have some data related to braking system. This data is relative and varies with application.

Table 1: Design Consideration

Mass of vehicle with occupants	600 kgf
Maximum velocity of vehicle	11.11 m/sec
Acceleration of vehicle	3.33 m/sec^2
Input driver force	160 N
Pedal ratio	7:1
Coefficient of friction of road material (μ_r)	0.7
Coefficient of friction of pad material (μ_p)	0.5
Factor of safety	3
Master cylinder stroke	15 mm
Master cylinder diameter	19 mm

2.1 Calculation of Clamping Force

Force of Master Cylinder Piston

$$F_{m\,c} = 160 \times 7$$

$$F_{m\,c} = 1120 \text{ N}$$

Area of Master Cylinder Piston

$$\text{Area} = \pi/4 \times d^2$$

$$= \pi/4 \times 19^2$$

$$A_{m\,c} = 283.52\text{mm}^2$$

Pressure applied by Master Cylinder

$P_{mc} = F_{mc} / A_{mc}$

$= 1120 / 283.52$

$= 3.95\ N/mm^2$

Pressure loss due to Fluid Transmission = 6% of P_{mc}

$P_{mc} = 3.713$

a) Calliper Piston Diameter = 25 mm
b) Caliper Material = Heat treated cast aluminum 354
c) Tensile Strength = 380 N / mm²

1) Area of Calliper Piston = $\pi/4 \times d^2$

$A_{cp} = \pi/4 \times 25^2$

$= 490.87\ mm^2$

According To Pascal's Law,

$P_{mc} = P_{cp}$

$3.713 = F_{cp} / A_{cp}$

$F_{cp} = 3.713 \times 490.87$

$F_{cp} = 1822.6\ N$

There are two Caliper Piston,

$F_{cp} = 2 \times 1822.6\ N$

$F_{cp} = 3645.2\ N$

Hence, Clamping Force = 3645.2 N

2.2 Calculation of Rotor Dimensions

Material of rotor = Steel 321

Tensile strength= 721 N / mm²

Static Load = 600 kg

Wheel base = 1000 mm

Height = 484.8 mm

Acceleration of vehicle (a) = 3.3 m/sec²

Load Distribution

Front (40%) = 240 kg

Rear (60%) = 360 kg

Dynamic weight distribution

For front wheels

$\Psi = M_f / M = 240/600 = 0.4$

$X = h/WB = 304.3/1000 = 0.304$

$a_{max} = 3.3 / 9.81 = 0.336$

$M_f = [(1 - \Psi) + (X \times a_{max})] \times M$

$= [(1 - 0.4) + (0.304 \times 0.336)] \times 600$

$M_f = 421.18\ kg$

$W_f = 4132.8\ N$

Maximum Braking Force,

$F_{bf} = \mu \times W_f = 0.7 \times 4132.8 = 2892.9\ N$

Brake Torque Required

$T_{faxle} = F_{bf} \times R = 2892.9 \times 0.243 = 702.9\ N.m$

At each wheel,

$T_{ftire} = 351.4\ N.m$

Now, Required dia. of disc brake rotor

$T_{af} = (\mu_p \times \text{Clamping Force} \times 2) \times r_f$

$351.4 = (0.5 \times 3645.2 \times 2) \times r_f$

$r_f = 96.4\ mm \cong 97\ mm$

$D_f = 194\ mm$

From Standard Chart we select 200 mm & 4mm thick disc

Table 2: Specification of Front Disc

Parameter Name Parameter	Value
Outer diameter of the rotor disc	200 mm
Inner diameter of rotor disc	80 mm
Hole PCD	90 mm
Thickness of rotor disc	4 mm
Mass of disc	0.8Kg

2.3 Calculation of Maximum Temperature

In a braking system, the mechanical energy is transformed into a calorific energy. This energy is characterized by a total heating of the disc and pads during the braking phase. The energy dissipated in the form of heat can generate rises in temperature ranging from 300 °C to 800 °C. Generally, the thermal conductivity of material of the brake pads is smaller than that of the disc.

Heat generated when applying braking action on disc brake = kinetic energy

$= (M \times V^2) / 2 = (600 \times 11.11^2) / 2 = 30858.02$ Joule

Hg = K.E = 30858.02 Joule

Also, heat generation is

$Hg = m_d \times C_p \times \Delta t$

$30858.02 = 0.8 \times 586 \times \Delta t$

Therefore,

$\Delta t = 65.8°C$

Where, M = Mass of vehicle (Kg)

V = Linear velocity of vehicle (m/s)

m_d = Mass of disc (Kg)

C_p = specific heat (J / Kg. K)

Δt = temperature difference (°C)

Now, $\Delta t = (t_{final} - t_{initial})$

$65.8 = (t_{final} - 27)$

$t_{final} = 92.8$ °C

3. CATIA MODELS

Structural model of rotor is created using CATIA V5R19 modeling software. 3D model of rotor is as shown below.

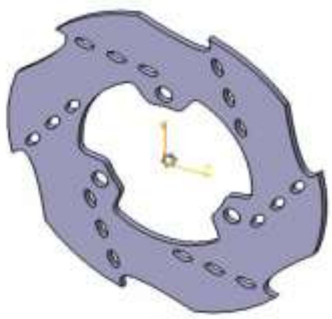

Figure 1: Rotor

4. ANALYSIS OF ROTOR

Analysis of rotor is done in ANSYS workbench 16.2. Following photos shows meshing, temperature distribution, and heat flux on rotor.

General procedure of analysis is as, first of all, 3D model of rotor is prepared in CATIA software. This file is transferred to ANASYS workbench software.

Model is prepared and all material properties are given. Then meshing is carried out. For better result fine meshing is done with curvature effect. Temperature constraints are applied on rotor and temperature distribution and change in heat flux is calculated on software.

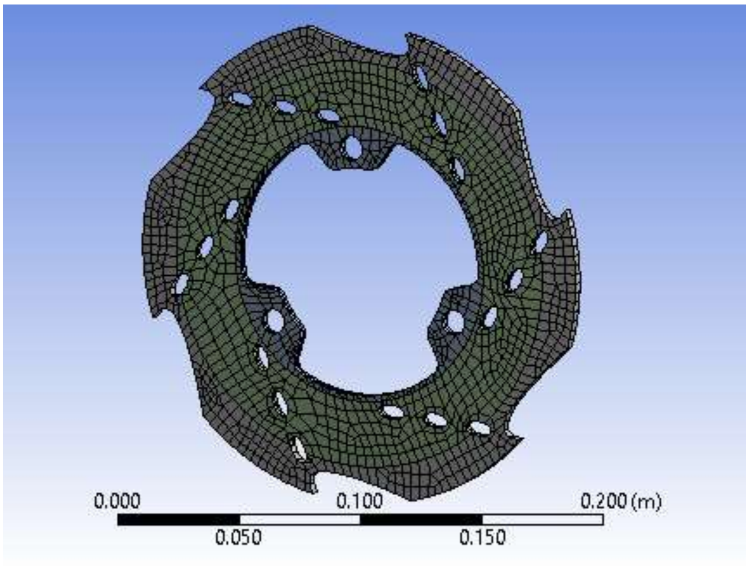

Figure 2: Fine Mesh with Curvature Effect

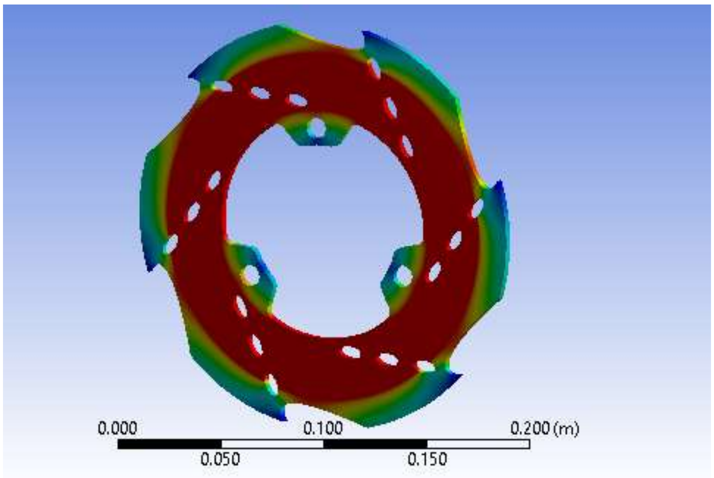

Figure 3: Temperature Distribution on Rotor

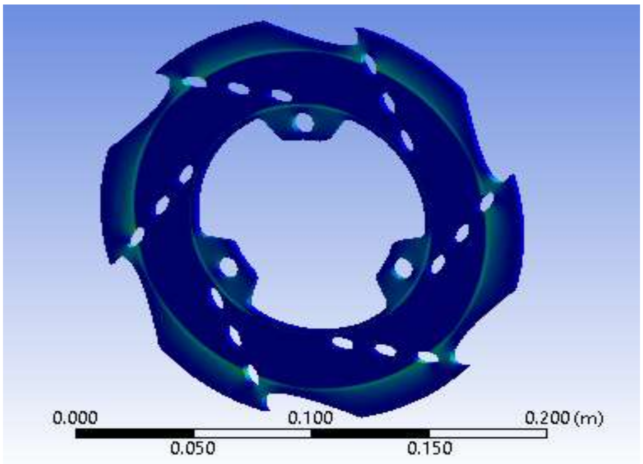

Figure 4: Heat flux on Rotor

5. CONCLUSION

Dimensions of rotor are accurately calculated by using basic principles of engineering. 3D model of rotor is prepared on CATIA software and thermal analysis is done in ANSYS software.

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