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Design and Analysis of Four Wheeler Brake Disc Rotor

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ABSTRACT

A Brake is a mechanical device which is used to slowing or stopping a moving object or preventing its motion. The brake disc is typically manufactured from cast iron, however in some cases it is made up of composites, and it is connected to wheel hub. The caliper having brake pads is mounted on the rotor. In order to stop the vehicle the brake pads must force towards the disc. The force applied on brake pads is generally in three ways such as hydraulic, pneumatic and mechanical. Present work deals with structural and thermal analysis of disc brake rotor of a vehicle. Heat generation and dissipation of disc brake rotor is analyzed. Further analysis is carried out to check heat flux and temperature distribution. CATIA V5R21 is used for the design and ANSYS 16.0 is used for the analysis of disc brake rotor. The objective of this work is to design and analysis of the disc rotor.

KEYWORDS: Brake disc, Hydraulic, Pneumatic, Heat flux, Disc brake rotor

I.INTRODUCTION

Exhaust valves are utilized in 4-stroke internal combustion engines to allow the exhaust gases to escape into the exhaust manifold. Due to the exposure to high The most important part of a vehicle is Brake system. Brakes are required to stop the vehicle within the possible distance and it is done by converting kinetic energy of the vehicle into heat energy by friction which is dissipated into atmosphere. The brakes are strong enough to stop the vehicle within the least possible distance. Brakes should also be consistent with safety. The driver should have a good control over the vehicle during panic braking. During the panic brake the vehicle should not skid. The brakes should have proper anti fade characteristics and their effectiveness should not decrease with application. A disc brake assembly consists of Disc rotor that rotates with the wheel, Calliper assembly attached to the steering knuckle, disc pads that are mounted to the calliper assembly.

This work shows a heat generation and dissipation of a disc brake of a vehicle during emergency braking and the following release period. Brakes which slows the vehicle and thus transforms kinetic energy into heat energy which results in heating of the brake disc. If the disc overheats the brake pads which fades and it can melt in rare cases.

II. LITERATURE SURVEY

Zaid, et al. (2009) a presented paper on investigation of disc brake by Finite element analysis. In this paper, the author has conducted a study on ventilated disc brake rotor of vehicle. This study is concern with heat and temperature distribution on disc brake rotor. In this paper, finite element analysis approached has been conducted in order to identify the temperature distributions of disc brake rotor. ANSYS has been used as finite elements software to perform the thermal analysis of disc brake. This study provides us an understanding on the thermal characteristic of disc brake rotor and to assist the automotive industry in developing optimum and effective disc brake rotor.

N. Balasubramanyam a transient analysis for the thermo elastic contact problem of the disk brakes with heat generation is performed using the finite element analysis. To analyze the thermos-elastic phenomenon occurring in the disk brakes, heat conduction and elastic equations are solved. The numerical simulation for the thermo-elastic behavior of disk brake is obtained in the repeated brake condition. The analytical results are presented for the distribution of heat flux and temperature on each friction surface between the contacting bodies.

Pratik P Numerical methods and analysis procedures used in the study of automotive disc brake. It covers Finite Element Method approaches in the automotive industry. This review can help analysts to choose right methods and make decisions on new areas of method development. The complex Eigen value method is choose for contact analysis of car disc brake. The essence of such a method lies in the asymmetric stiffness matrix derived from the contact stiffness and the friction coefficient at the disc interfaces. 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. It is also investigates different levels in modeling a disc brake system and simulating contact pressure distributions at varying load.

III. PROCEDURE

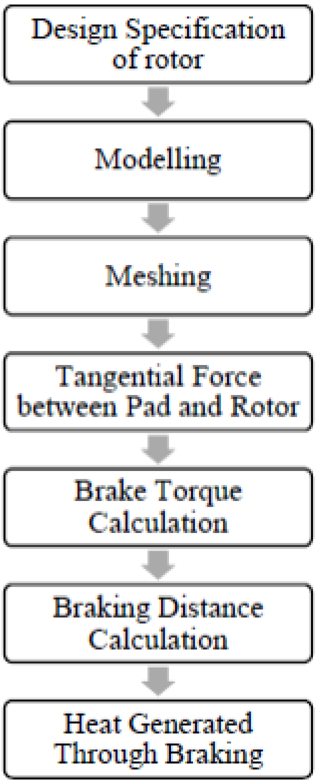

Figure 1: Flow chart of Design and Analysis

A. Design Specification of Rotor

Rotor disc dimension	215 mm
Rotor disc material	Cast stainless steel and aluminum.
Pad brake area	0.0067 m2
Pad brake material	Asbestos
Coefficient of friction (Wet)	0.07-0.13
Coefficient of friction (Dry)	0.3-0.5
Maximum temperature	350 ºC
Maximum pressure	1MPa (10e6 Pa)

B. Modelling of Rotor Disc

Modeling of disc brake is generated using CATIA V5 R20.The model of brake disc as 3D. The disc has a radius of 107.5mm and a thickness of 10mm

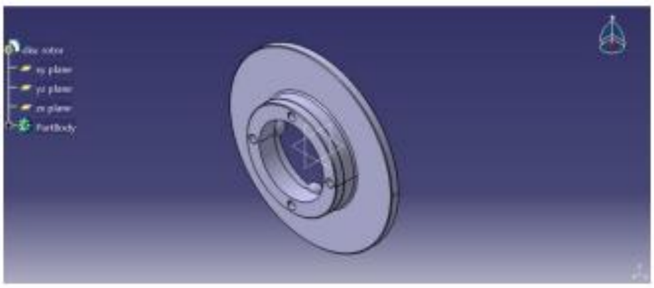

Figure 2: Rotor Disc

C. Tangential Force between Pad and Rotor (Inner Face)

FTRI = Normal Force between Pad brake and Rotor (Inner)

$\mu 1$ = Coefficient of Friction = 0.5

A = Pad Brake area

$$FTRI = \mu FRI \qquad \text{-Eq. (1)}$$

$$FRI = \left(\frac{P_{max}}{2}\right).A \qquad \text{-Eq. (2)}$$

So,

$$FTRI = \mu 1.FRI$$

FTRI = 0.5x0.5x1e6x0.0067

= 1675N

D. Brake Torque (TB)

Assumption of equal coefficients of friction and normal forces on the faces:

TB = FT.R -Eq. (3)

Where, TB = Brake torque

μ is the coefficient of friction, FT is the total normal forces on disc brake (inner and outer face) = 1675 N and R is the radius of rotor disc

TB = (1675) (120x10e^{-3})

= 201Nm

E. Brake Distance

We know that tangential braking force acting at the point of contact of the brake, and

WORKDONE = FT -Eq. (4)

Where FT is the total normal forces on disc brake and x is the distance travelled (in meter) by the vehicle before it come to rest. We know kinetic energy of the vehicle.

Kinetic Energy = $\frac{mv^2}{2}$ -Eq. (5)

Comparing Eq. (4) and (5)

FT.x = $\frac{mv^2}{2}$

Assuming,

V=100km/h = 27.77m/s and

m = 132kg. (Dry weight of Vehicle)

So, we get

x = $\frac{mv^2}{2FT}$ = 30.38m

F. Heat Generated through Braking

Heat Generated in disc rotor (J/s)

$$Q = mC_p\Delta T \qquad \text{-Eq. (6)}$$

Heat Flux (W/m^2)

$$q = \frac{Q}{A}$$

Q = 0.848*490*15 = 6232J

Heat Flux $\frac{Heat\ generated\ /_{Second}}{Area\ of\ disc}$ = 32560 W/m^2

Thermal gradient =32560/ 40=814 K/m

IV. COMPUTATIONAL FLUID DYNAMIC ANALYSIS GENERATION OF DISC BRAKE

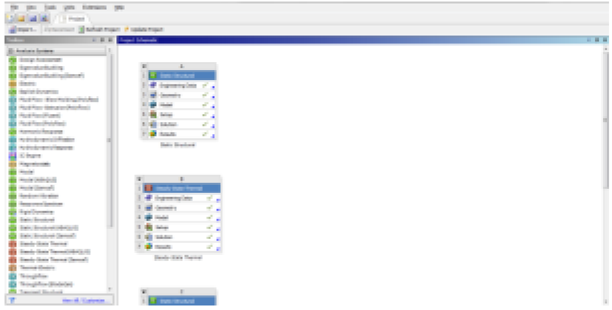

Figure 3: ANSYS16.0 Workspace

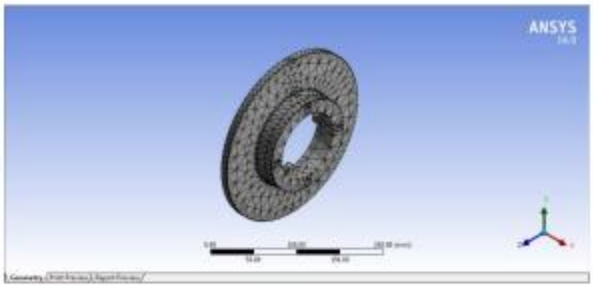

Figure 4: Generation of Mesh

V. RESULTS AND DISCUSIONS

A. Stainless Steel material under 3500N load

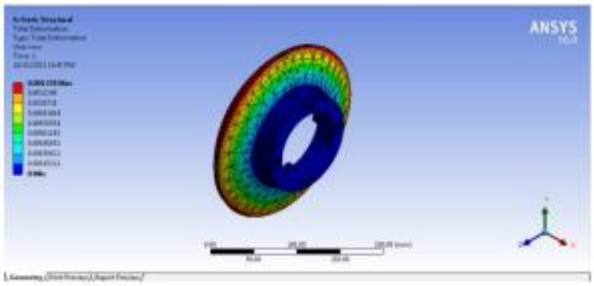

Figure 5: Total Deformation caused during Static Structural analysis

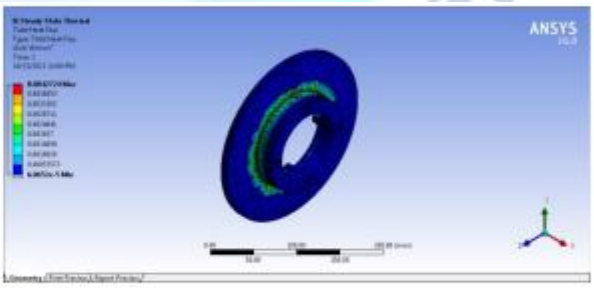

Figure 6: Total Heat Flux caused during Steady state thermal analysis

B. Aluminum alloy unter 3500N load

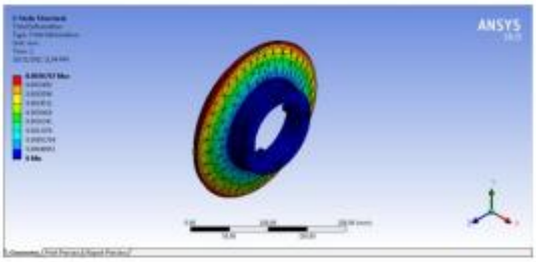

Figure 7: Total Deformation caused during Static Structural analysis

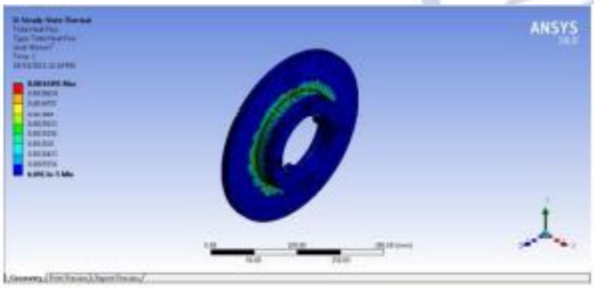

Figure 6: Total Heat Flux caused during Steady state thermal analysis

Table1: Results for Static Structural Analysis

Material	Weight	Stress (MPA)	Strain	Total Deformation	Directional deformation	Shear Stress(MPA)
Stainless Steel	3.082	3.1032	0.0000016101	0.001378	0.0000663	1.2452
Aluminum Alloy	1.1016	3.0681	0.000043246	0.0036767	0.00017827	1.2364

TABLE 2: RESULTS FOR STEADY STATE THERMAL ANALYSIS

Material	Weight (KG)	Temp (Celsius)	Total Heat Flux	Directional Heat Flux
Stainless Steel	3.082	53	0.0042724	0.0029288
Aluminum Alloy	1.1016	53	0.0044491	0.003058

VI. CONCLUSION

Here in this thesis we have designed a 4 wheeler disc rotor and done the thermal and structural analysis using Ansys software by optimizing the materials. For designing here we have used CATIA software.

As if we verify the results obtained the higher the heat flux the higher the heat dissipation, so here the heat flux is more for the material aluminum. And as if we verify the results obtained from the structural analysis here the results are almost equal for all the used two materials, and when we compare the deformations also there is a very slight negligible difference, so here all the two materials satisfies the product, but as if we compare the weights of the product outputs, here the aluminum and has very light weight when compared with the cast stainless steel. So by verifying all the obtained results we can conclude that the aluminum has accepted with the best output results with better performance.

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