Optimization and Analysis of Disc Brake

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Abstract - *The performance and success of any vehicle depend on the ability of its components to function properly under any conditions such as wet track, dry track, and off-road terrains. The performance of the vehicle can further be improved by making the components more robust along with the proper reduction in their weight. The safe operation of any vehicle requires constant adjustments of its speed under changing traffic conditions and the brake disc is an important component for the deceleration and maintaining the speed of a vehicle under control which includes stopping. This research paper studies an optimized design of the brake disc which aims at reducing weight and maintaining the strength along with reducing the deformation at higher temperatures as compared to the OEM available in the market. The brake disc is being modeled in SOLIDWORKS and analyzed via FEA in ANSYS for static and thermal loads.*

Key Words: Disc brake, Modal analysis, Weight reduction, increased strength.

1. INTRODUCTION

A brake is a mechanical device that uses absorbing motion by kinetic energy from and then convert it into heat energy. The disc brake is a type of braking system that uses a disc rotor is connected to the axle of wheel and a set of friction material called as brake pads (mounted on a component called brake caliper) is forced usually by hydraulic pressure against both sides of disc which causes it to stop with the help of friction. The most important parameter for any vehicle is the braking system. Compared to drum brakes, disc brakes better stopping efficiency.

2. LITERATURE REVIEW

Degenstein et al [1] this research paper deals with measurement of clamping force of brake pads in area of friction which is measured with help of thin pressure indication film which can be used only with stationary brake disc that is it cannot be used during the braking process. Since it is destroyed because of shear stress and friction.

Akshat Sharma and Amit Kumar Marwah [2] had done research on advantages of brakes after invention of engines, human race is very curious about speed, however with speed they have to stop it safely and efficiently so brakes play an important role in automobiles. Therefore, after various up gradation in technology of brakes, disc brakes come up with many advantages in field of efficient working as well as in weight.

K.Sowjanya and S.Suresh [3] have presented research paper which gives an overview of analysis of disc brakes. Brakes are mechanism system which is used to retard motion of moving body. Disc of brakes is made of cast iron or, aluminium composite. These are selected by running several tests on software likes Pro/E (Creo- Parametric) for solid modelling and static analysis are done by software likes ANSYS Workbench. Structural analysis is done to determine stress and deflection.

Vallamkondu Arun Kumar and Setty Kalyan [4] proposed a study which discusses usage of improving brakes by using various techniques. Thus, this to improve security parameters with respect to brakes. Taking overview on driver's reaction time this will help in collecting the data for assisting the driver.

ISHWAR GUPTA & GAURAV SAXENA [5] determined basic examination of rotor of disc brake of BAJA SAE 2013 CAR through limited component investigate approach by using ANSYS programming. The main goal of basic examination of rotor is to think about and assess execution under serious conditions and to recommend best parameters of rotor circle like Flange Width, Wall Thickness and Material creation.

Aditya Pratap Singh et al [6] wanted to study this optimization of braking mechanism for least stopping distance and each wheel should be locked at same time. SolidWorks struct-static investigation and simulate are done to get a more efficient braking system which can give the better class for the customer. Off-road conditions are required for dynamic braking and all wheels locking simultaneously.

3. CALCULATION

Table -1: Calculation Values

Parameters	
Coefficient of friction (Road and Tyres)	0.7
Coefficient between brake pads	0.5
Height of C.G from ground (h) mm	514.85
Distance of C.G from rear axle (a) mm	794.23
Wheel base (L) mm	1600.2
Mass of vehicle kg	250
Wheel diameter (Front and rear) mm	482.6
Front and Rear Rotor diameter mm	220
Effective pad area m^2	1.8338×10^{-3}
Maximum speed km/h	60
Stopping distance m	5
Pedal ratio	4.8:1
Pad brake area mm^2	2000

3.1 Calculation for De-acceleration

$V^2 - U^2 = 2as$

$0 = 16.67^2 + 2a\times5$

$-10a = 277.556$

$a = -27.78\ m/s^2$

3.2 Calculation for stopping time

$V = U + at$

$0 = 16.67 - 27.78t$

$t = \frac{16.67}{27.78}$

$t = 0.6$ sec

3.3 Calculation for weight distribution and required braking force

Front Wheel

$R_F = W \times (a + \text{coefficient of friction}\times h) \times \cos\left(\frac{b}{h}\right)$

$= 2452.5 \times \frac{794.26+0.7\times514.85}{1524}$

$R_F = 1858.13N$

3.4 Mass on front axle during dynamic condition

$= \frac{1858.13}{9.81}$

= 189.41 kg

Mass transfer on front axle during braking = 189.41 kg

Front braking force required for front axle = 189.41 × 27.78

= 5261.86 N

Force required for each wheel = $\frac{5261.86}{2}$

= 2630.93 N

Torque required for each wheel = $F_{\text{Front wheel}}$ × Wheel radius =618.137 N m

$T_{\text{Front wheel}} = T_{\text{Front rotor}}$

$T_{\text{Front wheel}} = F_{\text{rotor}} \times$ rotor radius

$F_{\text{Rotor}} = \frac{T\ Front\ rotor}{rotor\ radius}$

$= \frac{618.137}{0.1092}$

F_{rotor} = 5659.56N

$F_{\text{Clamp}} = \frac{4559.56}{0.5}$

F_{clamp} = 11319.12 N

$F_{\text{Clamp}} = F_{\text{Call}}$

F_{Call} = 11319.12 N

P_{Call} = 11319.12 / Effective area of pads

= 11319.12 / (2 × 1.833 × 10 $^{-3)}$

$= \frac{11319.12}{2 \times 1.833 \times 10^{-3}}$

P_{call} = 3086246.44 Pa

$P_{\text{Call}} = P_{\text{mc}}$

$F_{\text{mc}} = 3086246.44 \times 4.90625 \times 10^{-4} = 1514.186$ N

3.5 For rear wheel

$R_r = 2452.2 \times \frac{1602-794.26-0.7\times514.85}{1602}$

= 684.75

Mass = $\frac{684.75}{9.81}$

= 69.80 Kg

Force on rear wheel = ma

= 69.80×27.78

= 1939.04 N

Torque required for rear wheel = Wheel Radius $\times$ F_{Rear} = 0.254×1939.04

= 492.51 N-m

$F_{Rotor} = T_{rotor}$ / rotor diameter

= $\frac{492.51}{0.10922}$

= 4509.33N

$F_{Clamp} = F_{Rotor}$ / coefficient of friction

= $\frac{4509.33}{0.5}$

= 9018.66N

P_{Call} = 9018.66 / (Effective Pad Area)

=2134515.18 Pa

F_{MC} = $2134515.18 \times 4.90625 \times 10^{-4}$

= 1047.25 N

3.6 Total braking effort required on foot pedal by driver =

$F_{MC} = F_{MC1} + F_{MC2}$

$=1514.1896 \times 2 + 1047.25$

= 4075.6293 N

3.7 Braking efficiency = Vehicle weight / Brake effort

= $\frac{2452.5}{4075.6293}$

= 60.18%

4. Material Selection

Table -2: Property

Parameters	
Density (g/cc)	2.81
Ultimate Tensile Strength (MPa)	572
Tensile Yield Strength (MPa)	503
Elongation at break (%)	11

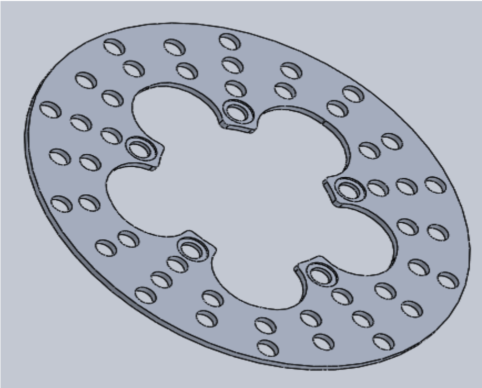

Fig -1: Model of Disc Brake

5. Analysis

Disc brake rotor analysis is conducted in ANSYS 19.0 software. Steady-state thermal and static structural analysis conducted for an existing and modified disc. Deformation and equivalent stresses of the disc are evaluated in static-structural analysis. Heat flux and temperature is evaluated in steady-state thermal analysis. This analysis is performed for obtaining the best combination of a disc brake rotor.

6. Results

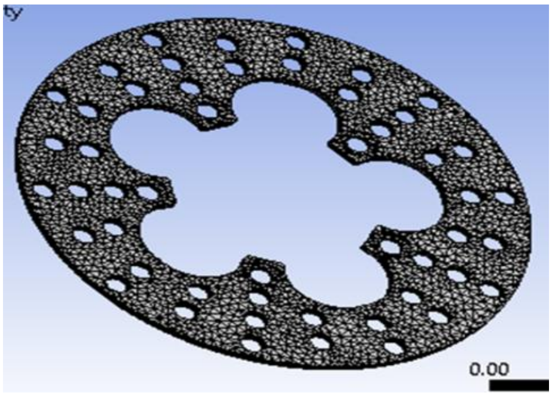

Fig -2: Mesh Model

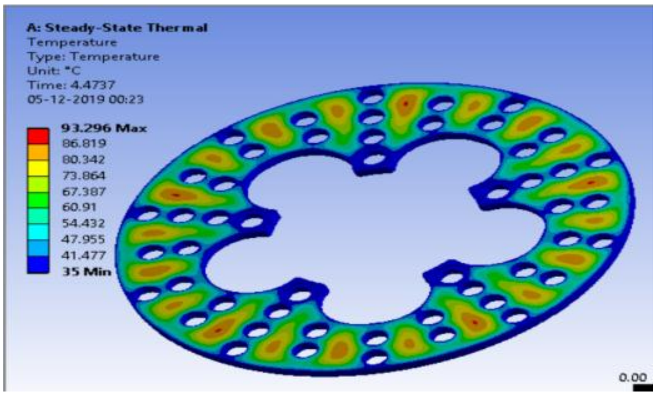

Fig -2: Steady State Thermal

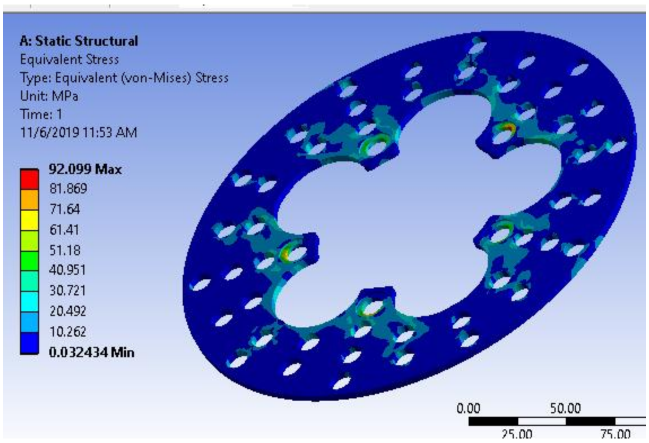

Fig -3: Equivalent Stress

7. CONCLUSIONS

1. All stresses are under allowable stress in structural analysis.
2. From the set of values, the best outcomes are found at deformation is 0.014503 mm, stress 92.09MPa and temperature at 93.296 C on AL-7075 T6 with 5 mm thickness.

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