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Design Optimization and Analysis of Brake Caliper

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Abstract - *In automotive engineering, safety is given prime importance. Efficient Braking system along with good steering & suspension systems, good handling and safe cornering are important in determining the performance of the vehicle. The objective of the presented work is to optimized the existing design according to the requirement and design of the brake caliper. This presented work also determines the design of piston diameter and bore diameter to fulfil the breaking requirements. Hence best suitable design is presented based on the safety and input criteria.*

***Key Words*: Optimization, custom brake caliper, Manufacturing components, Braking system, piston diameter, FEA, Simulation, Brake Pad.**

1. INTRODUCTION

In braking, a brake caliper plays great significance role as the final clamping force on a brake disc is applied by the friction pads. At the time of braking, pressure is applied on the piston which pushes the Brake pads against brake disc resulting in frictional force on brake disc and gradually decreases the motion of the vehicle.

A brake caliper which is mounted on upright mainly holds the friction pads, while the clamping force is applied by the piston. Braking torque is the main parameter while considering braking, whose value must have to be greater than the torque required to stop the vehicle. This can be achieved by applying clamping force on the brake rotor which causes reactive forces thereby inducing stresses in the caliper body. The applied clamping force results into frictional force and heat is generated which is dissipated by rotor and pads i.e. the kinetic energy of a vehicle is converted into heat which increases the disc temperature. This heat then transferred to the caliper body through the brake pads causing various deformation.

1.1 Optimization process

The optimization is performed by various software here the topology optimization is performed (1). This tool reduces the excess amount of material from the product with minimal change in fos and the final dimension and design is to be concluded according to the manufacturing process performed. Here the design is finalized with respect to easy machineability

Also, there are other modern tooling options such as regenerative design which Automatically provides the design with our considerations e.g. design according to FOS, design according to weight and many so outputs is provided according to the input parameter

The CAD modeling of the caliper was designed using Solidworks. Static structural analysis of the CAD model was carried out in ANSYS by applying the forces and pressure.

1.2. Calculations

The calculation is carried out and the diameter of the piston is decided according to various parameters like stopping distance required, clamping force required, master cylinder used and many (7). The calculation is carried out according to the required output. (2).

Table -1: parameters of vehicle

Calculation Assumptions			
Weight	250 kg	Weight distribution	40: 60
Track	52”	Base	56”
Master cylinder piston Diameter	19 mm	CG height	23”
Pedal Ratio	6:1	Fluid line Diameter	3 mm

We are applying up to 200N force on pedal.

Rotor Diameter = 160mm
Tire Diameter = 584.2mm
Torque on shaft = 400Nm
Length of shaft = 150mm

Static Load: -

Front axle:

$$W1 = (W*C)/L$$

$$= (250*9.81*568.96)/1422.4$$

$$= 981N$$

Rear axle:

$$W2 = (w*c)/L$$

$$= (250*9.81*853.44)/1422.4$$

= 1471.5N

Where,

W = load in N = weight*g

C = longitudinal distance of the center of gravity from rear

Axle in mm

L = wheel base in mm

Dynamic Load: -

H1 = height of front CG = 508mm

H2 = height of rear CG = 406.4mm

Front axle = W1 + (a*w*H1)/(g*L)

= 981 + (4.88*250*9.81*508)/(9.81*1422.8)

= 1416.71N

Rear axle = W2 – (a*w*H2)/(g*L)

= 1471.5 - (4.88*250*9.81*406.4)/(9.81*1422.8)

= 1122.93N

Where,

a = Deceleration (m/s^2)

w = weight in N

H = height of axle from ground in mm

L = length of base in mm

Stopping Distance = Velocity^2/ (2*co efficient of friction*g)

= 12.5^2/ (2*0.5*9.81)

= 15.92 meter

Stopping Time = 2*d / initial velocity + final velocity
= 2*15.92 / 0 + 12.5
= 2.56 Second

a = final velocity - initial velocity / time stopping
= 0 – 12.5 / 2.56
= -4.88 m/s^2

Caliper Force: -

Area of master cylinder piston:

A1 = **π** * r1^2

= 3.14 * 9.5^2

= 283.52 mm^2

Area of the calliper piston:

A2 = **π** * r2^2

= 3.14 * 17^2

= 907.46 mm^2

Master cylinder piston force:

F1 = Applied force * Pedal ratio

= 200 * 6

= 1200 N

Caliper piston force:

F2 = A2 * F1 / A1 (By Pascal Law)

= 907.46 * 1200 / 283.52

= 3840.82 N

2. Design in cad software

Modeling of caliper is designed as per calculation of the piston diameter, assembly constraints in the wheel rim (5).

Fig -1: section of brake caliper

Fig -2: cad model of brake caliper

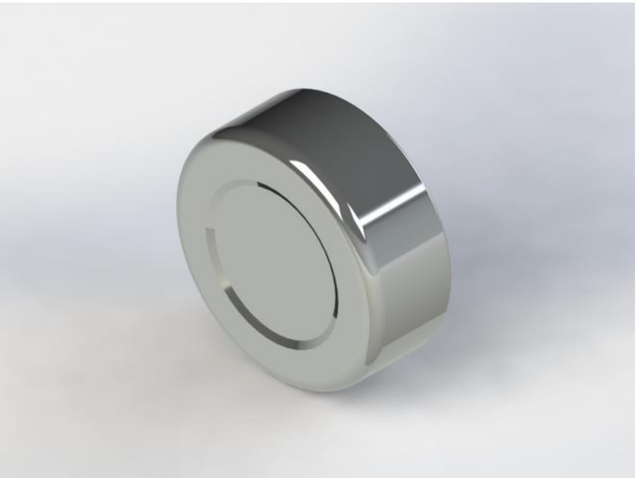

Fig -3: cad model of piston

3. Finite Element Analysis

This model was analyzed by applying the forces and pressure. Static structural analysis of the CAD model was carried out in ANSYS (3). The Structural analysis calculates area of deformations, stresses induced in the model, and strains on model in response to specified constraints. Analysis provides the information about model. For example, a static analysis provides us that the material will withstand the stress or it will break under stress (stress analysis), where the part will break (strain analysis), and how much the shape of the model changes (deformation analysis).After the numerical calculations, all the parameters such as bore diameter, seal groove, mounting, etc. are decided and then the CAD modelling of the caliper was designed in solidworks. The material selected for caliper is Al – 7075 and piston is EN 8. The parameters are presented in below table

Table 2 – parameters for Materials

No	Parameter	Value AL 7075	Value EN 8
1	Density	2710 kg/m^3	7800 kg/m^3
2	Young's Modulus	72 GPa	190 Gpa
3	Yield Strength	460 MPa	465 Mpa
4	Ultimate Strength	540 MPa	700 Mpa

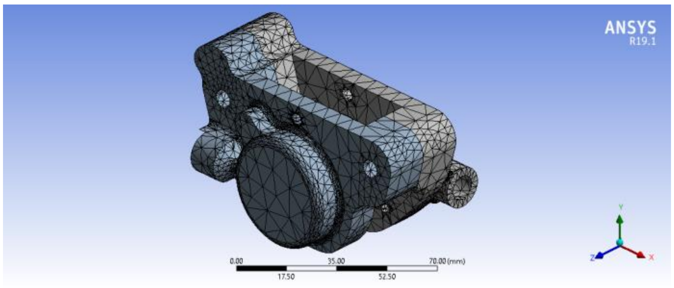

Fig -4: FEA model of brake caliper

4. Simulation in CAE software

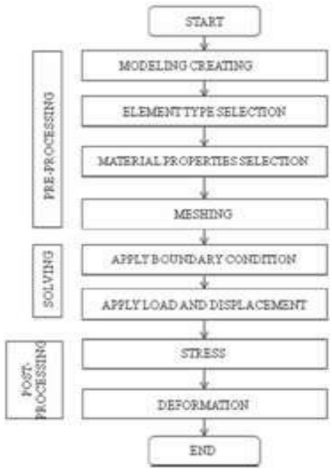

Chart -1: Flowchart of structural analysis (2)

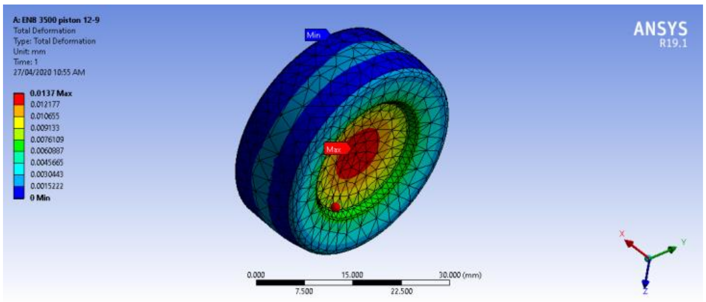

Fig -5: stresses in piston

After the analysis, the deformation of the piston was found to be 0.01 mm maximum and average of 0.004mm.

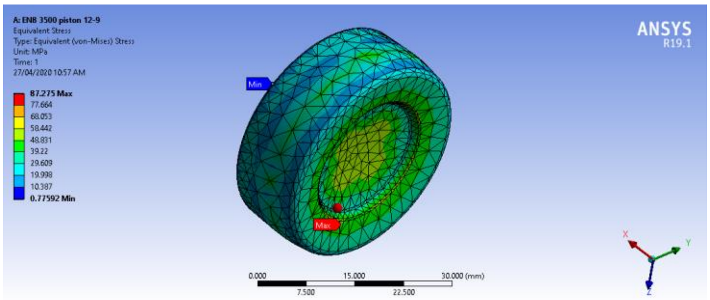

Fig -6: total deformation in piston

After the analysis the stresses were 87.275 MPA.

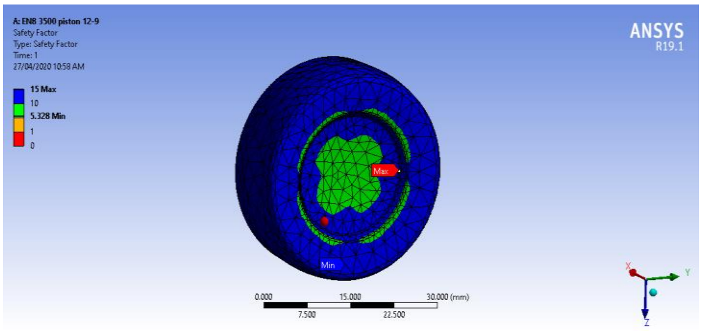

Fig -7: factor of safety of piston

After the analysis the factor of safety obtained is 5.32.

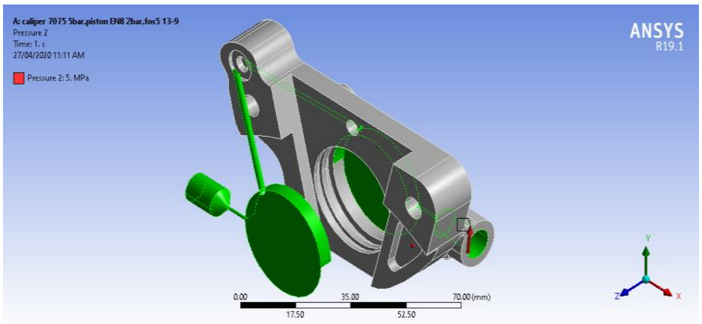

Fig -8: Applied pressure surface in brake caliper

The input parameter, applied pressure is 5 Mpa,

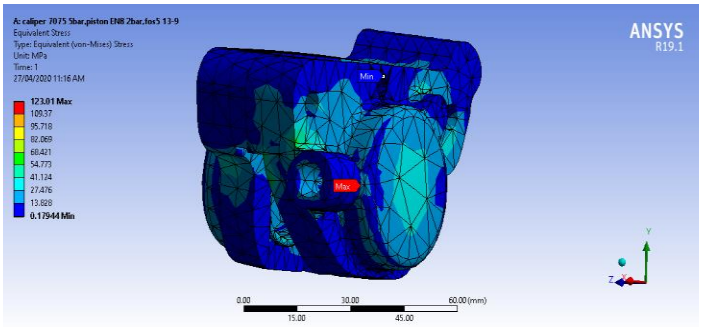

Fig -9: stresses in brake caliper

After the analysis the stresses were 128.1 MPA.

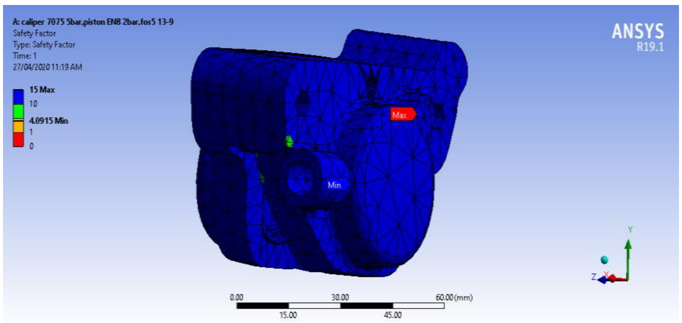

Fig -10: factor of safety of brake caliper

After the analysis the factor of safety obtained is 4.

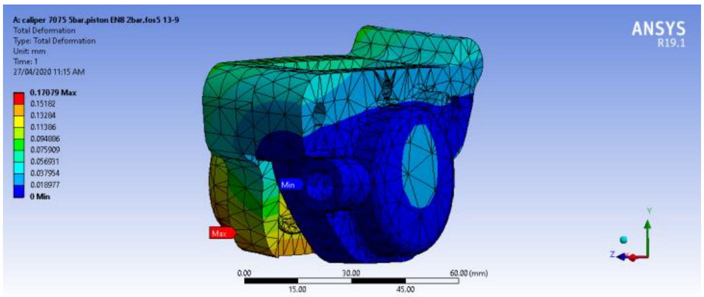

Fig -11: Total deformation in brake caliper

After the analysis, the deformation of the brake was found to be 0.17mm maximum and average of 0.04mm.

5. Manufacturing of components

The selection of Oil seal (9) and brake pad depends on various criteria, proper dimensions must be selected accordingly

Fig -12: final product piston & oil seal

The selection of brake pad material is carried out according to the co efficient of friction required and abrasives must be mixed accordingly.

Fig -13: final product brake pad & brake caliper

Fig -14: working condition of brake caliper

6. CONCLUSIONS

The objective was to design an effective, safe, durable braking system. The calculations have shown the required parameters for designing the system. The layout is analyzed and tested on different terrains. The brakes have proven to be effective and suitable for our system.

The purpose of weight reduction has also been fulfilled compared to the OEM calipers in the market.

Also, the maintenance time for brake caliper has been reduced compare to the OEM calipers due to the specific allocation of bleeder valve.

REFERENCES

[1] Adarsh.K.R., Akshay.S., Asish.R., Athish.S.U., Mebin Kuriakose Optimized Brake Disc Design using Topology Optimization Vol. 3, Issue 1, January 2017

[2] Mr. Prashant Patel, Prof. M.A.Mohite Design optimization of passenger car front brake disc for improvement in thermal behavior, weight & Cost reduction 2017 IJEDR | Volume 5, Issue 2 | ISSN: 2321-9939

[3] DHANANJAY PHAD, TEJAS AUTI, RUCHA JOSHI SWAPNIL JADHAV & SAGAR DEVASTHALI DESIGN AND ANALYSIS OF A BRAKE CALIPER Vol. 5, Issue 5, Oct 2015, 1-10

[4] Swastik Praharaj, Sidhisagar Mishra, Biswajit Tripathy, Arka Chatterjee, Alok Pattnaik DESIGN OF DUAL PISTON FIXED CALIPER FOR AN ALL TERRAIN VEHICLE Vol-5 Issue-5 2019

[5] Sameer Ingale, Sanket Kothawade, Aditya Patankar and Rohit Kulkarni, Design and Analysis of A Brake Caliper. International Journal of Mechanical Engineering and Technology, 7(4), 2016, pp. 227–233

[6] Akshay Naikwadi1,Prof. C.S.Wadageri2,Prof. K.Y.Bidari, “DESIGN OPTIMIZATION OF DISK BRAKE ROTOR” Volume: 04 Issue: 09 | Sep -2017.

[7] Á. Horváth – I Oldal – G. Kalácska OPTIMAL PISTON’S DIAMETER RATIO IN FOUR PISTON CALIPER

[8] Lucas Travi Farias, Adriano Schommer, Bruno Ziegler Haselein, Paulo Soliman, Leandro Costa de Oliveira Design of a Brake Caliper using Topology Optimization Integrated with Direct Metal Laser Sintering

[9] Okon D. Anwana, Hao Cai and H. T. Chang Analysis of Brake Caliper Seal-Groove Design

[10] “Bosch Automobile Handbook”, 4th edition, October 1996. ISBN-10: 0837616867

[11] . Thomas D. Gillespie “Fundamentals of Vehicle Dynamics” (Warrendale, SAE, 2014), ISBN-10: 1560911999

[12] Domond, Kenneth, 2010. 'Brake Rotor Design and Comparison Using Finite Element Analysis: An Investigation in Topology Optimization'. Master, University of California