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DESIGN AND ANALYSIS OF A BRAKE CALIPER

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Abstract - *Effective braking is a critical factor determining the performance of any vehicle. Brake caliper being the heart of a braking system, it is built considering its strength. An optimized design of a brake caliper thereby ensures reduced size of wheel assembly, reduced weight. This Report studies a conceptual design of a brake caliper for an All-Terrain Vehicle (ATV), primarily focusing on reducing the size and weight without compromising its strength. Computer aided design model of a brake caliper is created in CATIA V5 and analyzed for stress and deformation in ANSYS Workbench 18.1.*

***Key Words*: Brake caliper, Braking System, Rod Seal, Wiper seal, Analysis.**

1. INTRODUCTION

Braking System converts Vehicle Movement into heat by applying clamping force using friction pads on brake rotor. This is done by applying pressure on back side of piston pushing the brake pads against the rotor disc causing frictional force at contact and decelerates the vehicle. The main function of Brake Caliper is to multiply the force applied by the driver, support the brake pads and apply the clamping force. The pressure distribution over the friction pads must be uniform so as to ensure even pad wear and heat distribution. This is achieved by good choice of material, manufacturing precision and the design of caliper. The components of a brake caliper are as follows:

1. Caliper Body
2. Piston
3. Rod Seal
4. Wiper Seal
5. Brake Pads
6. Fluid Inlet
7. Bleed Point
8. Rubber Boot for retaining
9. Stud

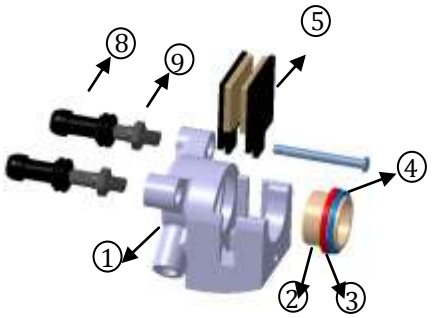

Fig -1: Exploded View of Brake Caliper

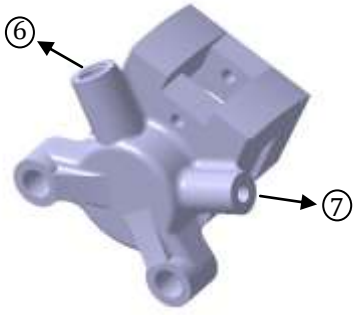

Fig -2: Brake Caliper Body

2. DESIGN CALCULATIONS

When the driver applies brakes, the pedal force gets converted into hydraulic pressure in the Master cylinder. This pressure, which acts as an actuating force, is transferred through the brake fluid to the caliper. Here the actuating force gets converted into the clamping force. Magnitude of this force depends upon the bore diameter. The clamping force pushes the friction pads against brake rotor thereby generating a frictional force between them which is responsible for braking torque. The generated braking torque must be greater than the required torque to stop the vehicle. Required braking torque on a particular wheel is calculated from the load on the corresponding axle. Thus, the piston diameter and the bore diameter are calculated according to required braking torque. The calculations are as follows.

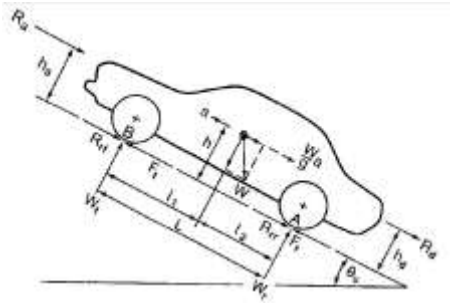

Fig -3: Free Body Diagram

2.1 Assumptions and Data

- W_f =reaction of the ground on front wheel
- W_r= reaction of the ground on rear wheel
- Tr= Torque required
- a= retardation of the vehicle =0.7g (max)
- μ =coefficient of friction between ground and tire = 0.7
- μ_p =coefficient of friction between pad and disc = 0.35
- R=Radius of tire=11inch =0.2794m
- R_d =Radius of disc
- P_c=Pressure in Braking system
- FOS= Factor of safety

- Required braking torque is given by equation

$$Tr = \frac{W\ Dynamic\ on\ front\ wheels * \mu * Radius\ of\ tire}{2}$$

- Clamping Force is given by equation

$$Fc = \frac{Tr * FOS}{2 * Rd * \mu p}$$

- Frictional Force = $\frac{Tr}{2 * Rd}$

- Diameter of caliper is calculated by

$$D=\sqrt{\frac{4*Tr*FOS}{\pi*Pc*\mu p*Rd}}$$

3. MATERIAL SELECTION FOR CALIPER BODY

Caliper is a component of braking system which is used for applying the required torque on the rotor, should have high strength. The main aim to decrease the weight without compromising on strength so aluminum 7075 is selected for its light weight and strength

Table -1: Properties of Aluminum 7075

Sl. No	Property	Value
1	Density	2700 kg/m^3
2	Young's Modulus	72 GPa
3	Yield Tensile Strength	503 MPa
4	Ultimate Tensile Strength	590 MPa

4. SELECTION OF ROD SEAL AND WIPER SEAL

4.1 Rod Seal

Rod seals are typically single-acting seals, which means that fluid pressure acts from inside the cylinder on one seal side only. Pressures acting on the rod side of the is very high. The pressure acting on the rod seal increases contact forces between the rod seal and rod surfaces. Therefore, rod seal materials should be worn resistant. The rod seal is chosen from SKF catalogue as per required.

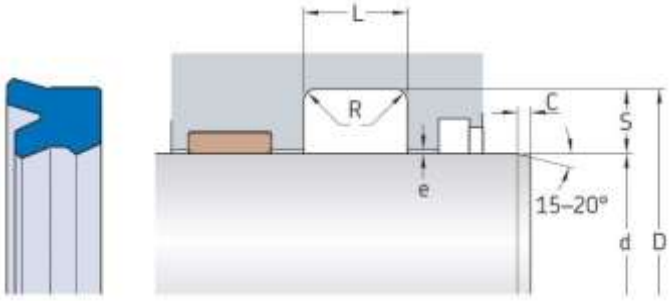

Fig -4: Rod Seal

4.2 Wiper Seal

Brake caliper operates in a variety of environmental conditions, including exposure to dust, debris or outside weather conditions. To prevent these contaminants from entering the Piston assembly, wiper seals (also known as scrapers, excluders or dust seals) are fitted on the external side of the cylinder head. The Wiper seal is chosen from SKF catalogue as per required.

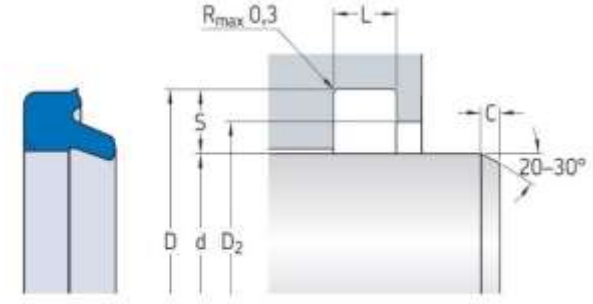

Fig -5: Wiper Seal

5. MODELLING OF CALIPER

Modelling of caliper is done in CATIA V5 as per requirement of piston diameter and assembly constraints.

Fig -6: CAD Model of Caliper Body

6. ANALYSIS

After modelling of caliper body is done it was analyzed using ANSYS Workbench 18.1 by applying forces and pressure. The material used are of Aluminum 7075 as mentioned above.

The caliper body is mainly subjected to following loads:

1. Pressure inside the cylinder
2. Clamping force
3. Frictional force

6.1 Loading Conditions

- Clamping Force is given by equation

$$Fc = \frac{Tr * FOS}{2 * Rd * \mu p} = 3800N$$

- Frictional Force is given by equation

$$Ff = \frac{Tr}{2 * Rd} = 1500N$$

- Pressure in Braking Circuit= 6 MPa

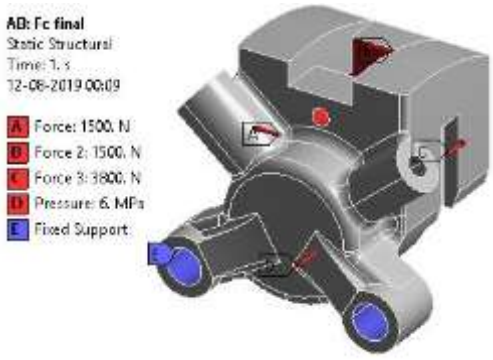

Fig -7: Loading Conditions of brake Caliper

7. RESULTS AND DISCUSSION

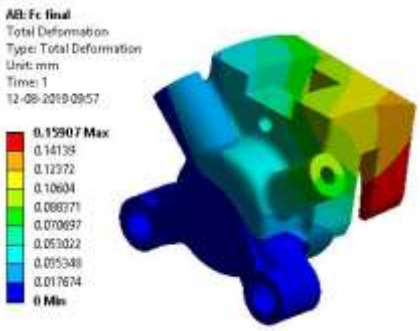

Fig -8: Total Deformation of brake Caliper

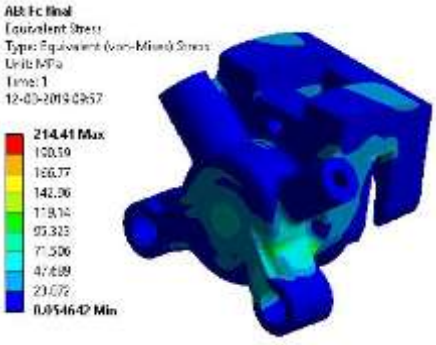

Fig -9: Equivalent stress (Von-misses) of brake Caliper

Table -2: Maximum Deformation and Stress

Maximum Deformation	0.159 mm
Maximum Stress	214.4 MPa
FOS	2.34

8. CONCLUSIONS

The following statements can be concluded:

1. The most important aspect is to determine the Braking force and generated braking force should be greater than required.
2. Selection of seals is the most important for a brake caliper to function proper.

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