Design Of Dual Brake Caliper System

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Abstract - As the safety of the driving force is paramount in such events there's a requirement to style and fabricate a secure and reliable braking system. Single CALIPER brake is already available which is suitable for day-to-day life but the goal here is to provide something with better power in terms of braking power allowing the vehicle to stop at a lesser distance than the single CALIPER system in case of an emergency which will prevent accidents. 'DESIGN OF DUAL BRAKE CALIPER SYSTEM 'it is a new innovative approach which will provide the user a safer vehicle with better braking power of a vehicle.

Key Words: Brakes, Disc Brake, Safety, Reliable Braking system, Brake Power.

1.INTRODUCTION

Dual brake caliper system is needed at present situation due to increased acceleration and high speed of vehicles with the presence of a high torque providing engine/motors.

Single caliper brake is already available which is suitable for day-to-day life but the goal here is to provide something with better power in terms of braking power allowing the vehicle to stop at a lesser distance than the single caliper system in case of an emergency which will prevent accidents.

This will not only provide better braking in a high-performance vehicle but in a passenger vehicle if used the brake power will be split into two different calipers and will be absorbed by four brake pads hence increasing the life of not only the brake pads but also the brake rotor and increasing the service interval of brakes and reduce maintenance

The benefit of the dual rear brake system is in helping to slow down heavy race cars without the phenomena of brake fade since the braking force is being split between two calipers anf four brake pads on each side of the vehicle.

The system can handle more abuse effectively because of the number of pads is doubled and hence handling the braking is improved.

Dual brake caliper system can not only be used it high performance vehicle but can be used it all the vehicles and will be very efficient.

1.1 PROBLEM STATEMENT

Increasing accidents due to high speed and higher acceleration with rapid throttle response the brakes are not able to keep up with the car in emergency situations hence the vehicle is out of control and it spins or losses traction.

Dual brake caliper can make the difference and can provide better braking and reduced number of accidents with better vehicle stability and better control.

Dual brake caliper is cost efficient and will give better results as compared to single brake caliper.

1.2 OBJECTIVES

To design and experimental analysis dual brake calipers on a single disc and make the system more reliable, failsafe & increase the efficiency keeping the maintenance costs in mind. The goal here is to provide something with better power in terms of braking power allowing the vehicle to stop at a lesser distance than the single CALIPER system in case of an emergency which will prevent accidents

2. METHODOLOGY

The objectives identified to accomplish the goal were:

• Studying and identifying the present mechanisms

• Identifying the potential problem through abstraction. • Collecting useful data.

• Interpreting data as the problem definition

• Developing of design on concept and then selection based on the logic approach procedure for product design and development.

• Finally preparing the embodiment design of the product

- Design of mount and caliper.
- Positioning of caliper
- Fabrication of mount and caliper housing assembly.
- Fabrication of drive shaft
- Installation of mount and dual calipers.
- Installation of rotor
- Installation of wheel lug.
- Installation of drive shaft.
- Testing for heat dissipation
- Testing of brakes.
- Testing of braking power.

3. PROBLEMS IN CONVENTIONAL DISC BRAKE

3.1 BRAKE FADE

Brake fade is temporary loss of braking power which usually occurs as a result of very high

Temperatures in the friction material. The heat reduces the coefficient of friction between the friction material and therefore the rotor, and leads to reduced braking effectiveness and ultimately failure.

3.2 BRAKE FLUID VAPORIZATION

If temperatures during braking is more than the boiling point of the hydraulic fluid, then the process of brake fluid vaporization will occur. A vapor lock will then form in the hydraulic circuit, and as gas is more compressible than liquid the pedal stroke is used to compress this gas without actuating the brakes.

3.3 EXCESSIVE COMPONENT WEAR

High temperatures within the braking system can form thermal deformation of the rotors resulting in uneven braking, accelerated wear and premature replacement. The lifetime of the friction material is additionally temperature dependent, at higher temperatures chemical reactions within the friction material may cause a breakdown in its mechanical strength, which reduces braking effectiveness and causes rapid wear. The wear of frictional material is directly proportional to contact pressure, but exponentially associated with temperature, therefore more rapid wear will occur at elevated temperatures.

3.4 THERMAL JUDDER

On application of the vehicle's brakes, low frequency vibrations may occur, these vibrations can be felt by the driver as body shake, steering shake and in some cases an audible drone, this phenomenon is known as 'judder'. Two types of judders exist; hot (or thermal judder) and cold judder. Cold judder is caused by uneven thickness of the rotor, referred to as disc thickness variation, this results in deviations in touch pressure because the pads connect with the rotor. This leads to uneven braking or brake torque variation. The second type is called thermal judder which will occurs due elevated temperatures, and is caused by thermal deformation of the disc.

3.5 DISSIPATION OF WARMTH FROM DISC BRAKES

The rise in temperature of the brake disc in any braking operation will depend upon variety of things including the mass of the vehicle, the speed of retardation, and therefore the duration of the braking event. within the case of short duration brake applications with low retardation, the rotor and friction material may absorb all of the thermal energy generated. As a result, little or no cooling occurs because the temperature rise within the rotor is minimal. In extreme braking operations like steep descents or repeated high speed brake applications, sufficient cooling becomes critical to make sure reliable continued braking

3.6 STRIATIONS AND GROOVES ON THE FRICTION RING

The friction ring of the brake rotor has horizontal grooves on the contacting surface of brake pads. It I caused by contamination or foreign bodies between the brake pad and disc and Brake pad of unknown origin with poor quality which end in reduced braking function, noises and increased wear.

4. DUAL BRAKE CALIPERS

The DUAL CALIPER rear brake design isn't common today, even among super cars, hyper cars or other high-performance exotics. However, double CALIPERs are used on some high-performance motorcycles also as on back-engine dragsters – where they're prized for his or her ability to resist brake fade, especially after continuous runs. Use of DUAL CALIPERs increases the importance of getting greater stopping power for the rear tires in comparison to the fronts. With a single-piston CALIPER, the footprint of pad is restricted in some ways to the diameter of the piston. The diameter can only grow so large in reference to the rotor and restraint . If the pad is just too long, it flexes. When the pad gets warm it expands, it creates an uneven friction for coupling on the disc'sface.

The uneven friction can create unwanted noise. If the flexing is sever enough, the friction material can break away the backing plate. An example of this is often the first Chrysler Neon. Also, there's an immediate relationship between the diameter of the rotor and therefore the diameter of the only piston CALIPER.

This system introduces design and fabrication of dual brake calipers and it mount to extend the braking power of a vehicle. this is often a replacement innovative approach which can provide the user a safer vehicle with better brakes at minimum cost.User are going to be ready to drive a vehicle with better confidence and greater reliability on brakes knowing that it's failsafe with decreased braking distance.

Here system provides most benefit to high performance vehicle. the essential concept here is to supply more braking force, thus this may enable the vehicle to return at rest early and hence increase road safety. By adding an additional caliper we are providing more surface are for contact which can generate more brake power hence reducing stopping distance.Dual brake caliper can make the difference and can provide better braking and reduced number of accidents with better vehicle stability and better control. Dual brake caliper is cost efficient and will give better results as compared to single brake caliper.

5. BRAKE CALCULATIONS

5.1 PRE-REQUISITE DAT A FOR CALCULATION

Mass of the Buggy: 210kg
Bore diameter of the master cylinder: 19.05mm
Force on pedal: 400N
Coefficient of friction between brake pedal and rotor: 0.4 = dry pads & 0.1 wet pads.
Coefficient of friction between road and tire: 0.7
Velocity of the buggy: 13.88 m/s
Bore radius of CALIPER piston: 45mm
Tire radius: 12.1 in
Percentage of weight in the front: 45%
Percentage of weight in the rear: 55%
Pedal ratio-6:1
Fbp= Force output of the brake pedal assembly
Fd= Force applied to the pedal pad by the driver
L2 & L1 = Distance from the brake pedal arm pivot to the output rod to
brake pedal pad.
Pmc= Hydraulic pressure generated by the master cylinder
Amc= the effective area of the master cylinder hydraulic piston Fcal= the one- sided line mechanical force generated by the CALIPER
Acal= the effective area of the CALIPER hydraulic pistons found
on one half of the CALIPER body.
Fclamp = the clamping force generated by the calliper between pad and rotor
Ffriction = the frictional force generated by the brake pads opposing the rotation
of the rotor.
μbp = the coefficient of friction between the brake pad and the rotor. b = Bore diameter master cylinder piston, mm.
bp = Bore diameter of CALIPER piston, mm.
Reff = the effective radius of the rotor.
Vv = velocity of moving vehicle. av= the deceleration of the vehicle.

Brake Pedal Force:

$$F_{bp} = F_d \times \left(\frac{L2}{L1}\right)$$

$$F_{bp} = 400 \times \left(\frac{6}{1}\right) = 2400\ \text{N}$$

Master Cylinder Pressure:

$$P_{mc} = \left(\frac{F_{bp}}{A_{mc}}\right)$$

$$A_{mc} = \left(\frac{\pi \times b^2}{4}\right) = \left(\frac{\pi \times 19.05^2}{4}\right) = 285.02\ mm^2$$

$$P_{mc} = \left(\frac{2400}{285.02}\right) = 8.42\ N/mm^2$$

Force Generated by CALIPER Piston:

$$F_{cal} = P_{mc} \times A_{cal}$$

$$A_{cal} = \left(\frac{\pi \times b^2}{4}\right) = \left(\frac{\pi \times 45^2}{4}\right) = 1590.431\ mm^2$$

$$F_{cal} = 8.42 \times 1590.431 = 13391.43\ N$$

CALIPER clamp Load:

$$F_{cl} = F_{cal} \times 2$$

$$F_{cal} = 13391.43 \times 2 = 26782.86\ N$$

Force on disc by brake pads:

$$F_{friction} = F_{cal} \times \mu_{bp}$$

$$F_{friction} = 26782.86 \times 0.4 = 10713.144\ N$$

$$F_{friction} = 26782.86 \times 0.1 = 2678.29\ N$$

Torque of rotor: R_{eff} =0.7

$$T_r = F_{friction} \times R_{eff}$$

$$T_r = 10713.144 \times 0.7 = 7499.2\ Nm$$

Force on a tire:

$$F_{tire} = \left(\frac{T_t}{Rt}\right)$$

Force on front wheel $F_{tire} = \left(\frac{7499.2}{12.15}\right) = 617.22\ N$

Force on rear wheel $F_{tire} = \left(\frac{7499.2}{12.15}\right) = 617.22\ N$

Total force: F_{total} = 617.22 + 617.22 + 617.22 + 617.22 = 2468.88 N

Deceleration of vehicle:

$$a_v = \left(\frac{F_{total}}{mv}\right)$$

$$a_v = \frac{2468.88}{210 \times 9.81} = 1.198\ m/sec^2$$

Stopping Distance (50 kmph)

$$SD_v = \frac{Vv^2}{2 \times av} \qquad SD_v = \frac{13.88}{2 \times 1.198} = 5.8\ m$$

$$\text{For two CALIPERs} = \frac{5.8}{2} = 2.9\ m$$

Stopping Time

$$S_t = \frac{Vv^2}{av} \qquad S_t = \frac{13.88}{5.8} = 2.4\ sec$$

$$\text{For two CALIPERs} = \frac{2.9}{2} = 1.45\ sec$$

Static front weight = Total weight × (45/100)
=210× (45/100) = 927.045 *N.*

Static rear weight = Total weight × (55/100) = 210× (55/100) = 1133.055N

Absolute weight transfer:

(1.198 × 30.48 × 210 × 9.81) / (9.81 × 243) = 31.56 N

Dynamic front weight:

Static front weight+ absolute weight transfer

= 927.045 + 31.56 = 958.605 N

Dynamic rear weight:

Static rear weight-absolute weight transfer

=1133.055 – 31.56 = 1101.495 N

Dynamic front torque:

dynamic front weight × tire radius × friction between tire and road

= 958.605 × 12.1 × 0.7 = 8119.4 N

Dynamic rear torque:

Dynamic rear weight × tire radius × friction between tire and road

= 1101.495 × 12.1 × 0.7 = 9329.66 N

Minimum effective rotor diameter:-

Front: = (2×front tire torque)/front clamping force

= (2×8119.4)/ (26782.86)

= 0.606 mm=0.024 inch

Rear: = (2×rear tire torque)/rear clamping force

= (2×9329.66)/ (26782.86)

= 0.697 mm = 0.027 inch

Brake heating:-

Kinetic energy = (1/2)×m × v2

=0.5×210×13.88×13.88 = 20228.7 J

Braking kinetic energy is converted into thermal energy: **ΔTb** = (KE) / (m_b × Cp)

= (20228.7)/ (210 × 0.683) =141.03 °C.

Heat Flux =

$$\frac{\text{Heat Generated} \times .7}{\text{Stopping Time} \times \text{Area of Rubbing} \times 2}$$

$$= \frac{20228.7 \times .7}{11.6 \times 0.0213 \times 2} = 28654.9 \left(\frac{W}{m^2}\right)$$

Rotational energy = 0.03×20228.7 = 606.861

Braking time = velocity/deceleration

= 13.88/1.198 = 11.6 sec

6. DESIGN & ANALYSIS

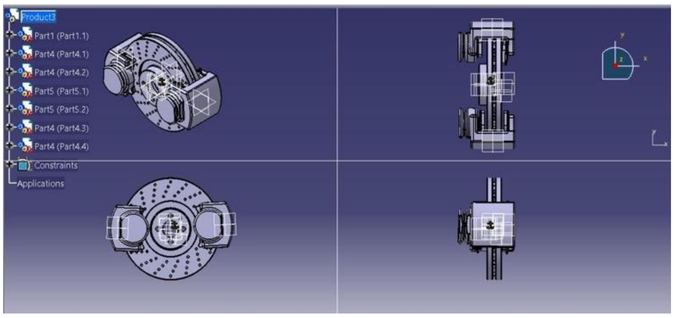

Fig-1: 3D design on Catia V5

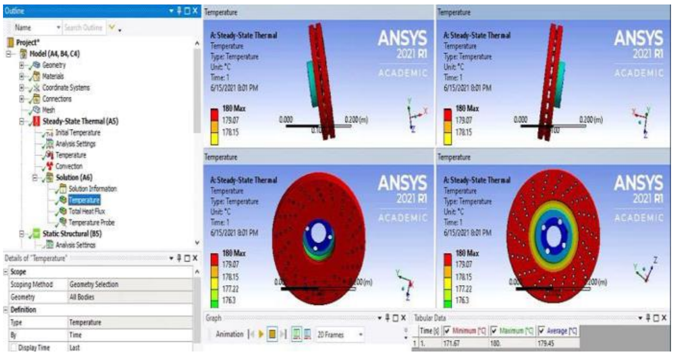

Fig-2: Steady- State Thermal (Temperature)

Fig-3: Steady- State Thermal (Total Heat Flux)

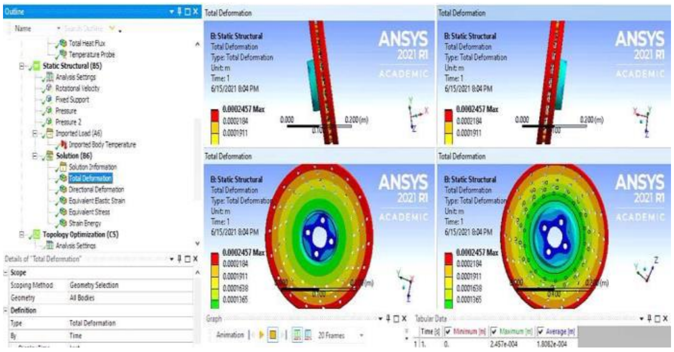

Fig-4: Static Structural (Total Deformation)

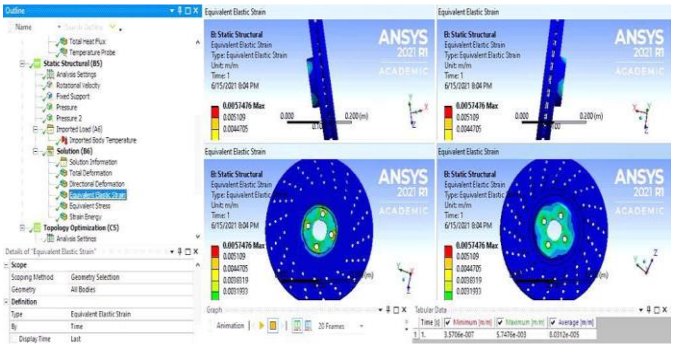

Fig-5: Static Structural (Equivalent Elastic Strain)

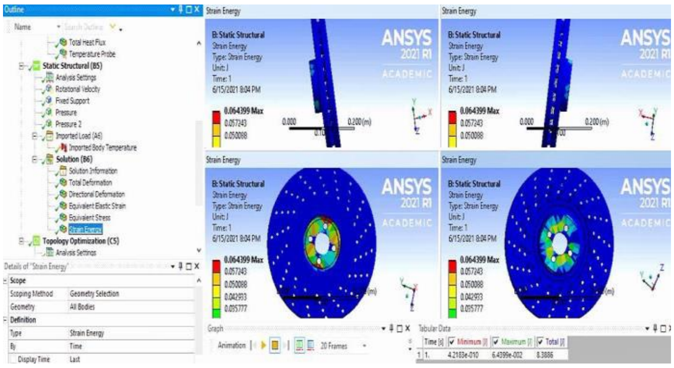

Fig-6: Static Structural (Strain Energy)

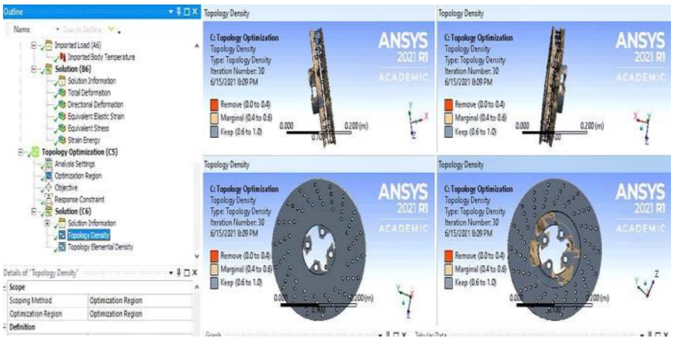

Fig-7: Topology Density

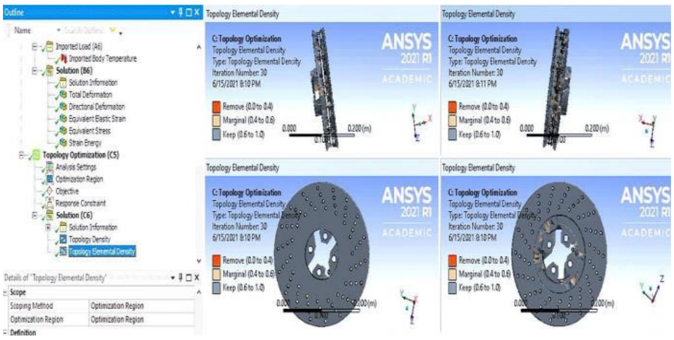

Fig-8: Topology (Elemental Density)

7. COMPARISON OF SINGLE BRAKING SYSTEM WITH DUAL BRAKING SYSTEM

Single CALIPER Braking	Double CALIPER Braking
• Uses single CALIPER for braking of automobile.	• Uses dual CALIPERs for braking of automobile.
• Single CALIPER are always sliding CALIPERs that move slightly because the resistant wears.	• Double CALIPER are fixed CALIPERs which doesn't move when brakes are applied.
• The restraint here are just Two in numbers.	• It consist of Four restraint which are placed at two different CALIPERs.
• The pressure distribution here is confined to the pads with their areas.	• The pressure here are often distributed evenly and over to large area.
• The pads here absorb less initial heat and produce more thermal shock.	• The massive pads will absorb more initial heat and produce less thermal shock.
• The braking force required to prevent the vehicle is restricted to 2 disc.	• The braking force required is just half of single CALIPER as it has fourrestraint.
• Higher dissipation in comparision to double braking mechanism.	• Lower cooling as break force is reduced to half the cycle.
• The pads wear off fast because it has just two pads used for breaking.	• The wear and tear off pads is slower because the contact is been getting distributed equally.
• Stops vehicle at a distance hooked in to speed of automobile i.e 5-10m .	• Stops vehicle before the limiting distance even with much less brake force.
• The hub here is smaller amount weighted just one single CALIPER is been mounted on the rotor.	• The hub here is more weighted as it had two CALIPERs mounted on rotor.

Table-1: Comparison of brakes

8. ADVANTAGES

- In the area of drag and fuel savings. With dual- or twin pistons, it's possible to possess more aggressive piston seals which will pull back the pads more effectively after the driving force removes his foot from the pedal . Double the pistons means greater strength to crack down on the rotors.
- Double the restraint means twice the contact area of the pads with the rotors total swept area .
- Twice the CALIPERs and brakes means the hardware has got to work half as hard when stopping the car, thereby allowing them to chill off twice as fast and eliminating brake fade during instances of continuous hard braking.
- The use of it's going to hamper heavy race cars without brake fade since the braking force is split between two CALIPERs on all sides of the vehicle.
- The larger pad is in a position to soak up more unwanted noise and vibration because it's ready to cover more of the rotor

9. DISADVANTAGES

- The slides and bushings play a critical role on dual CALIPERs. If there's an excessive amount of play, the CALIPER could rotate on the slides. this may cause uneven pad wear.
- For uneven pad wear. If the pads have tapered wear, it could mean a drag with the CALIPER. Tapered wear could mean that the slides are binding or that one piston might be exert more force than the opposite, or both conditions might be present.
- The pistons on dual CALIPERs could also be difficult to retract. Both pistons must be pushed back at an equivalent time and rate with special tools. If unequal

force is employed, it's possible to scrape the pistons against the bores. this will damage the finish and coatings on the pistons and bores. Also, it can damage the seals

- With more number of CALIPERs and pads greater weight and mass will be there which is the sworn enemies of performance.

10. FUTURE SCOPE

- Addition of ABS are going to be another advantage to the present system, it can help the driving force hamper or stop the car even more efficiently specially for rally/ racing drivers.
- Regenerative braking are often used with this project & the results are often observed
- Further tests are often performed with restraint of various materials and more efficiency are often gained for an equivalent system
- Improvement are often wiped out the ways to dissipate heat from the disc and restraint
- Combination of various size of brake calipers are often analysed.

11. RESULTS

FACTORS	VALUES Minimum	VALUES Maximum
Temperature	171.67 °C	180 °C
Total Heat Flux	20.49 $\left(\frac{w}{m^2}\right)$	18042 $\left(\frac{w}{m^2}\right)$
Total Deformation	0.000101 m	0.0002457 m
Equivalent Elastic Strain	0.00124 m/m	0.0057476 m/m
Strain Energy	0.01433 J	0.064399 J
Topology Density	0.24957	1.03

Table-2: Results

Deceleration of vehicle	1.198 m/sec^2
Stopping Distance For two CALLIPER	2.9 m
Stopping Time For two CALLIPER	1.45 sec
Dynamic front torque	8119.4 N

Table-3: Results

12. COST ESTIMATION

COMPONENTS	COST (₹)
Electric Motor	2870
Pillow Bearing	350
Pulley	500
Belt	300
Shaft	700
L-Shape Metal Plate	780
Brake Calipers (2)	6500
Brake Pads Set	1640
Brake Rotor	1170
Brake Hoses	600
Brake lever	1700
TOTAL COST	**17110**

Table-4: Cost Estimation

13. CONCLUSIONS

A systematic review of the system has been presented. In these numeric computations have been done to obtain braking forces, braking torque, Equivalent Elastic Strain & clamping forces at CALIPERs, brake bias and other important parameters in a braking system. Comparison has been done between the clamping force in the clamping force in one of the front wheels of car.

The designed braking system is effective, reliable and has minimum weight without any compromise in its safety standards and performance. Thermal Calculations for heat flux are done and film coefficient is determined which helps in the thermal analysis. The results of coupled steady state thermal and static structural analysis in Ansys have been shown. These results are quite satisfactory.

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