Design of Convective Cooled Mono-block calipers for an All-Terrain Vehicle

Akash Ingle[1], Kajal Paner[2], Kunal Shinde[3], Shubham Sutar[4]

[1]*Student,Department of Mechanical Engineering,D.Y.Patil College of Engineering,Maharashtra,India*
[2]*Student,Department of Mechanical Engineering,D.Y.Patil College of Engineering,Maharashtra,India*
[3]*Student,Department of Mechanical Engineering,D.Y.Patil College of Engineering,Maharashtra,India*
[4]*Student,Department of Mechanical Engineering,D.Y.Patil College of Engineering,Maharashtra,India*

ABSTRACT

The project is the part of an all-terrain vehicle built for an intercollegiate design competition called BAJA SAE. The motive behind choosing this topic for project was to get into the field of All Terrain vehicles, studying the various important parameters that are associated with the design of wheel assembly system for the purpose. Several assembly types and brake systems were researched. The main criteria were identified and special research was done in the field of heat dissipation of heat from hydraulic baking system evaluating the various alternatives. This resulted in choice of extremely light weight and optimized wheel assembly with completely new mono-block type hydraulic braking system. The testing was so done to test all design parameters. Testing proved that the designed system was rugged and performed well.

Keywords: *Wheel assembly, Mono-block, Convective cooled, Optimum Design, Weight, etc*

---

1. INTRODUCTION

Wheel assembly is the most critical area of any vehicle and when it comes to an all-terrain vehicle then the forces that come across the wheels are up to the material limits. Hence this project deals with various components that are strengthened not only on base of increased material properties but also by improving their optimum shape and features. Project extends the limits from Knuckle, Wheel hub, bearing selection to Hydraulic brake disc with completely new build convective cooled mono-block calipers. The new build brake calipers features the principle heat dissipation by convection by fins rather than just conduction through walls. Also its unique body design with rigid mono-block structure offers a caliper which withstands high braking pressures with substantially low weight.

1.2 Methodology1.1 Problem Statement

As in any braking system, heat dissipation is essential for operating the brakes without fading at higher temperatures. Approach was to generate a provision to dissipate the heat more efficiently, increase the strength, and reduce the calliper deflection (flexing) but keeping the weight under minimum limits. Also increase the strength of calliper.

2. Convective cooled mono-block Fixed Calliper:

The designed calliper differs from the conventional calliper in terms of design, manufacturing, mounting and most different heat dissipation method. Basic function of the calliper remaining same, that is converting the kinetic energy of the vehicle into heat energy to decelerate or completely stop the vehicle on drivers will. Calliper consists of two pistons on opposite ends faced with brake pads consisting of semi-metallic friction material.

2.1 Mono-block casing:

A brake calliper is responsible for application of clamping force by which the brake disc is squeezed in between the fiction pads. The maximum force that the calliper can apply on the disc depends on how stiff the calliper body is. Conventional OEM fixed type brake callipers are generally split in two halves, which are clamped together with axial bolts with considerable area of contact. The designed calliper is no split into two halves but machined from a single aluminium block and often known as mono-block design. As there is no separation in both the halves the casing is strong as the material strength offering larger area of contact. Stiffer casing delivers more ability to transmit the clamping force and withstand high hydraulic pressures up to 100 bars.

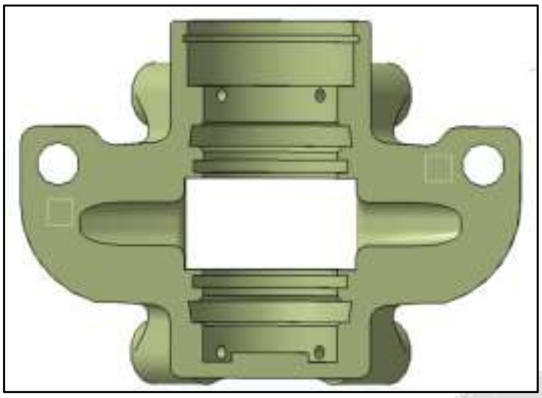

Fig1: Sectional view of Caliper

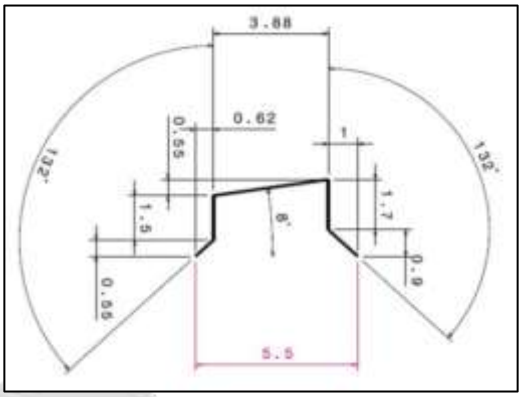

Fig 2: Geometry of groove

2.2 Unique Seal Groove Geometry:

Brake drag is an most significant unwanted phenomenon that takes place in various vehicles with continuous rubbing of brake pads with brake discs without application of brakes. And this mainly occurs due to insufficient piston retraction. This issue was encountered on many similar vehicles and research on the same gave rise to shape a unique seal groove geometry whose sole function is to retain the system pressure and secondarily it offers maximum piston retraction when the brakes are released. A OEM square cut seal easily fits in the groove and holds on for a longer life due to additional corner break features of the groove. Testing and validation resulted in successful piston retraction of 1 mm with this geometry of groove.

2.3 Cooling Fins:

As mentioned before, dissipation of heat generated while braking was countered by most innovative way. The generated heat between brake pads and the rotor is partially absorbed by the rotor and remaining travels through the brake pads. The heat which is transmitting through brake pads if not resolved then it gets transferred to calliper pistons and subsequently the brake fluid, which is not at all desirable .As the boiling of brake fuild beyond its boiling limits can degrade its properties and vapour formation takes place at higher temperatures which can lead to severe system failure. Heat dissipation in this design takes place directly from brake pads to the atmosphere via convection. Brake pads are extended above the callipers providing additional surface area by the cooling fins. Cooling fins work efficiently keeping the average temperature of the callipers about 38degree Celsius.

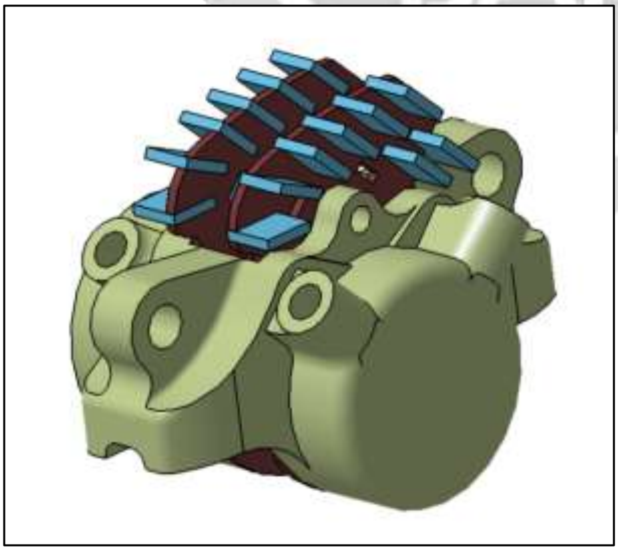

Fig 3 : Iso-metric view of Rear caliper

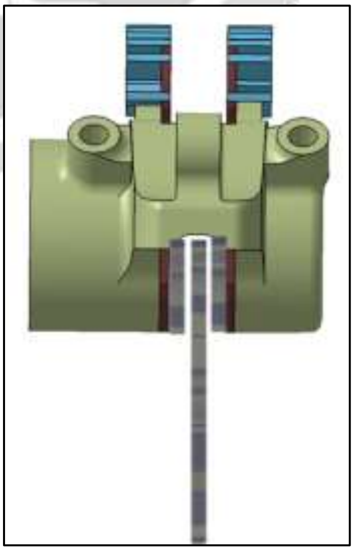

Fig 4 : FV of Rear Caliper

Specification

Callipers	Front - Single piston fixed calliper)
	Rear - Single piston fixed calliper)
Brake Fluid	DOT 4
Rotor material	Cast Iron FG 300

Table 1 : Calliper Specification

2.2 Design Procedure

The step by step process followed for designing the overall subsystem is given below

1. After getting the geometrical design constraints, the basic parameters of calliper such as piston diameter, piston deflection, retraction, length of piston, etc. where evaluated on trial and error method
2. After obtaining the basic parameters then the building of 3-D CAD model was done in Catia software.
3. Analysis of the CAD model was carried out in ANSYS by setting the constrains.
4. Calliper mounts were considered as fixed supports and the pressure force was applied in the cylinder area of the calliper.
5. Pressure upto maximum system pressure of 108 bar was applied and accordingly the calliper bridge thickness and calliper thickness was determined.
6. Thermal Analysis of calliper was also carried out in ANSYS with Transient Thermal Analysis.
7. CFD Analysis of Calliper was carried out to determine the rate of heat dissipation and set the required area of heat dissipationi.e. cooling fins.
8. Calliper with fins, and calliper without fins was analysed in CFD to get the comparison of improved heat dissipation.
9. The final CAD model of calliper was assembled with the wheel assembly and the mounting points of the callipers were obtained.
10. Finally, the assembly was simulated and adjustments were done to satisfy all the clearances. Final product was manufactured.

3.ANALYSIS

The Finite Element Analysis of various components of calliper was done using ANSYS Workbench 16.0.

3.1 FEA Results :

The results obtained from analysis of the components are in terms of Equivalent Stress Induced, Total Deformation and Factor of safety. The contour plot is obtained from the software with maximum and minimum tab showing the areas of concerns.

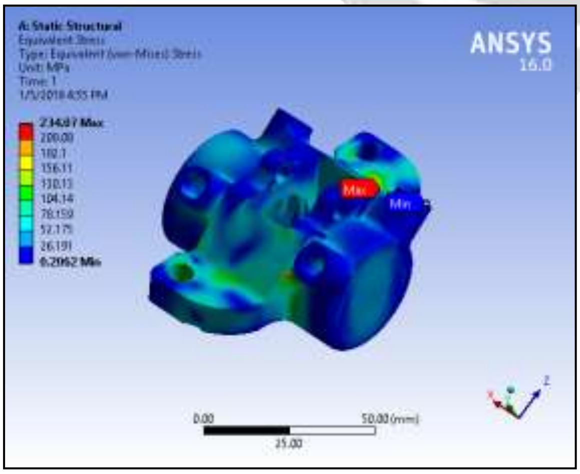

Fig 5: Stress result

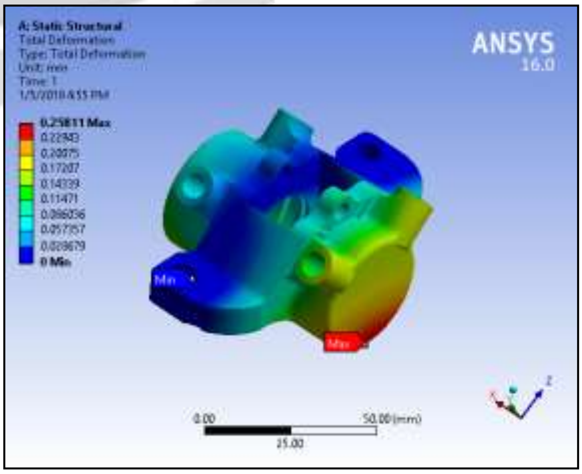

Fig 6: Deformation result

Component	Stress (MPa)	Deformation (mm)
Calliper casing	234.07	0.26

Table 2: Stress in casing

3.2 Convective Analysis:

To check the effectiveness of fins on caliper heat transfer analysis was done using Ansys fluent.

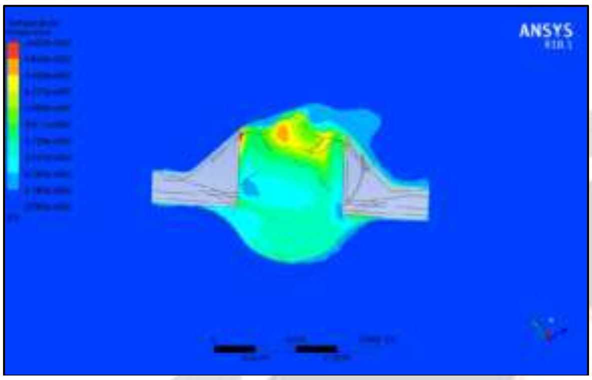

Fig 7. Temperature Contours

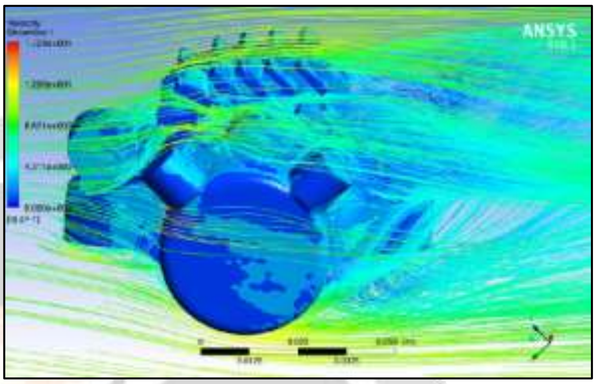

Fig 8. Stream lines

Temperature achieved	
With Fin	70^{0} C
Without fin	105^{0} C

Table 3 : Temperature

Parameters	Value
Caliper flexing	0.1 mm
Pad wear rate	800 mm/Km
Overall weight	**220gm**

Table 4: Caliper Parmeters

4.Final Component

Fig: Assembled caliper image 1

Fig: Assembled caliper image 2

5. Conclusion

The main objective of calliper is to apply maximum braking force to the brake disc without flexing and dissipate heat generated to run the brakes cooler

Thus, the calliper was such designed that provides a stiffer casing which applies maximum clamping force on the brake disc. Also cooling fins provide maximum heat dissipation rate through convective heat transfer and maintans the average temperature much below the allowable limits.The self-design parts were analyzed in ANSYS Workbench. All results were verified testing of the vehicle.

Thus we can concluded that the Convective cooled mono-block calipers n designed for ATV satisfies all the requirements, the same was verified by testing.

6.REFERENCES

[1] SAE Research Paper 970688
[2] Automobile Engineering by Kripal Singh
[3] Rudolph Lipert- Brake design and safety
[4] Brakes 2000 Handbook.