Design and Fabrication of Twin Integrated Hydraulic Master Cylinder

Akshay N Markad[1], Sangramsing D Parmar[2], Sachin R Patil[3], Anushree K Lakhapati[4],

Sunil S Patil[5]

[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*
[5]*Prof.,Department of Mechanical Engineering,D.Y.Patil College of Engineering,Maharashtra,India*

ABSTRACT

Making the things in "Nano" dimensions is the prime goal of today's era. Presuming the same as the base we are writing this paper on the design of a compact sized and light weight "Twin Integrated Hydraulic Master Cylinder". In vehicles each subsystem must comply all safety requisites. In automobile braking system the master cylinder is a controlling unit from which the braking action takes place, so we have focused on making the component more efficient and safer. Its feature of having four outlet ports and also complying the rule of having two independent hydraulic brake circuits in such a compact size makes it superior over the Tandem Master Cylinders present in the market. Also, its integrated body makes it superior over the use of an assembly of two different slave master cylinders along with splitters for the braking purpose in Formula type racing cars as well as commercial cars. It has provided with an extra mounting at the rear end in order to mount it vertically to reduce the space requirement of mounting assembly. Also, the same rear mounting can be use for an oscillating cylinder type arrangement with the help of ball joints to avoid the pedal force to break into its components leading towards an effective braking. Structural analysis has been performed on HYPERMESH. The experimental testing of master cylinder has been performed on Formula Student Vehicle and performance parameter such as stopping distance is recorded.

KEYWORD: *Master cylinder, twin integrated, compact size, feasible in assembly, structural analysis, braking distance.*

1. INTRODUCTION

The thesis work focuses on the designing and development in hydraulic master cylinder. The master cylinder is the heart of the hydraulic brake system. It consists of two main chambers. The fluid reservoir which contains the fluid to supply to brake system, and the compression chamber in which the piston operates. The reservoir supplies fluid to the brake system through two ports. The larger port is called the filler or intake port and is connected to the hollow portion of the piston between the primary and secondary cups which act as piston seals. The smaller port is called the relief, bypass or compensating port which connects the reservoir directly with the cylinder and lines when the piston is in released position.[2]

When the brake pedal is completely released, the master cylinder is in a static position. The cylinder bore and reservoir are equalized at atmospheric pressure because air vent and equalizing port are open.[2]

When the brake pedal is applied, piston is forced forward. Forward movement of piston begins to transfer fluid from the cylinder bore through equalizing port to reservoir and outlet port. Piston cup moves past equalizing port and prevents any additional fluid from flowing to the reservoir. After the` compensating port is sealed out then the pressure is generated in the system and the braking action will takes place.[2]

When the brake pedal is released, the input force is removed from piston. Brake system components under pressure now cause fluid to return to the master cylinder through outlet port. As the brake pedal returns to the static position, spring continues to retract piston. This creates a vacuum in the cylinder bore allowing fluid to pass over piston cup and replenish the cylinder bore. When piston cup is returned past equalizing port, bore and reservoir pressures are equalized.[2]

The tandem master cylinder available in market has some drawbacks viz it's length, weight, servicing issue, etc as per requirement of formula student racing car. In order to overcome the drawbacks of Tandem master cylinder we have made an attempt to design the Twin integrated hydraulic master cylinder.
CATIA software is used for Computer Aided Drawing and HYPERMESH & ANSYS software for Finite Element Method.
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1.1 Problem Statement

Design a hydraulic brake master cylinder for SAE-SUPRA vehicle. The design must have a good balance of lightness, reliability, efficiency, compactness, and cost-effectiveness.

1.2 Methodology

The project approach is based on Compactness of Master cylinder body. The target was to get optimum design for designed component. As it is heart of braking system its performance should be reliable and should comply all system requirements. As it is going to mount in cockpit region, its axial length should be minimum to reduce the cockpit length resulting increase in driver's visibility.

2. RESEARCH WORK

2.1 Cylinder body

The cylinder body is the most crucial part of master cylinder assembly. The bore of the master cylinder plays an important role in achieving the desired pressure .Lesser the diameter, larger is the pressure generated. If the cylinder body is not designed with proper strength, it would result in bursting of body. This could damage the complete system and can lead to huge financial as well as time loss. This damage of the system will lead driver to loss control on vehicle and may lead complete automobile in danger. So it's necessary to take proper precautions while designing the master cylinder's body. The components of master cylinder are cylinder body, piston, seal, spring, connecting rod,

The cylinder body has further two classification basis on the number and arrangement of the pressure chambers in the cylinder. First is slave master cylinder having a single pressure chamber. Second is tandem master cylinder having two pressure chambers arranged in series manner. Both of them have certain advantages as well as limitations. First, the slave master cylinder is discussed.

Slave master cylinder is easy to manufacture by casting process provided that the material used is Cast Iron. But the Cast Iron (density=7.874 g/cc) weighs more as compared to Aluminium (density=2.7 g/cc) for same component. If Aluminium is selected as casting material, then the cost of production increases as the Aluminium has largest liquid shrinkage as compared to Cast Iron. For a slave master cylinder, the axial length of the cylinder is smaller as it has single pressure chamber and a single output port. So, to complete the hydraulic circuit for all the four wheels, it needs two separate master cylinders along with hydraulic distributors. This causes overall increase in space requirement for the brake assembly. Also, such circuit increases chances of brake oil leakage. So in order to avoid the above difficulties, new type of a cylinder known as tandem master cylinder was invented.

In a tandem master cylinder, there are two pressure chambers are provided in a single cylinder in a series manner. Each pressure chamber has two outlet ports connecting to all four wheels. This type of arrangement makes the tandem master cylinder long along it's axis. It causes unnecessarily increase in vehicle's cockpit length and reduces driver's visibility.

To overcome all these limitations of a slave master cylinder as well as of tandem master cylinder, a Twin Integrated Hydraulic Master Cylinder is designed. In this, we have arranged two separate pressure chambers side by side in a single body and provided two output ports on each. Hence, the name "Twin Integrated". As this arrangement is very compact, it requires less space as compared to space required by assembly of two slave master cylinders. Also, eliminates possibility of leakage due use of hydraulic distributors. At the same time, the parallel arrangement of bores reduces cylinder body's axial length approximately by 60%. In addition, this arrangement allows use of balance bar for proper force distribution among front and rear wheels. We have also provided a separate mounting due to which a rotating cylinder type assembly is possible.

All the other components used are similar to that of readily available but designed as per requirement.

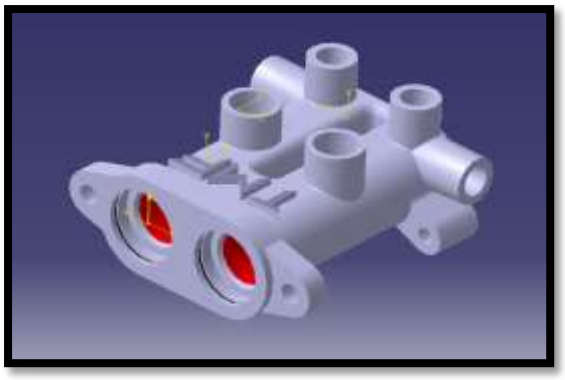

Fig -1: Twin integrated master cylinder body

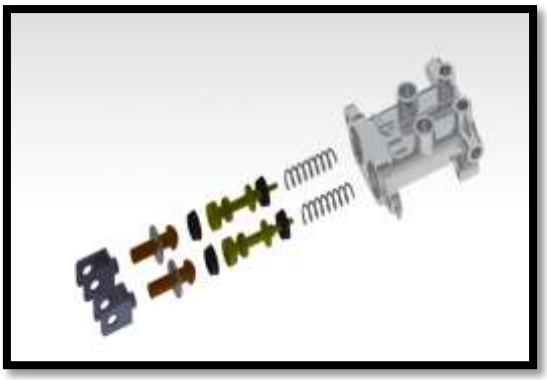

Fig -2: Exploded view of Twin integrated master cylinder assembly

2.2 Specification

- It has **twin dual bore** of **15.875 mm or 5/8 inch** each contains separate piston inside the cylinder bore
- These pistons are **parallel to each other** operating on **two separate** push rod connected to the single control with the help of c-clamp.
- There are two outputs from each cylinder bore.
- This Master cylinder has nearly **120mm** length including pushrod with C-clamp
- Maximum Stroke Length of this Master Cylinder is also nearly **25-30mm**
- It has two different types of mountings with which it can be mounted horizontally as well as vertically in very less space.

3. MATERIAL PROPERTIES

Material: Aluminium 6061

- Density: 2860 Kg/m^3
- Tensile Yield strength: 276 MPa
- Modulus of Elasticity: 69 GPa

4. ANALYSIS

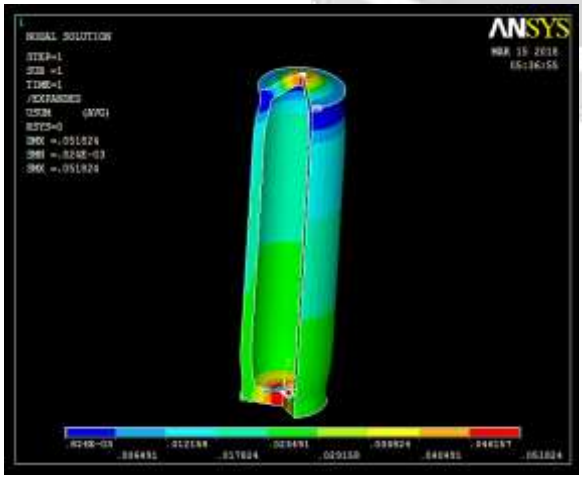

Fig -3: Deformation in cylinder body

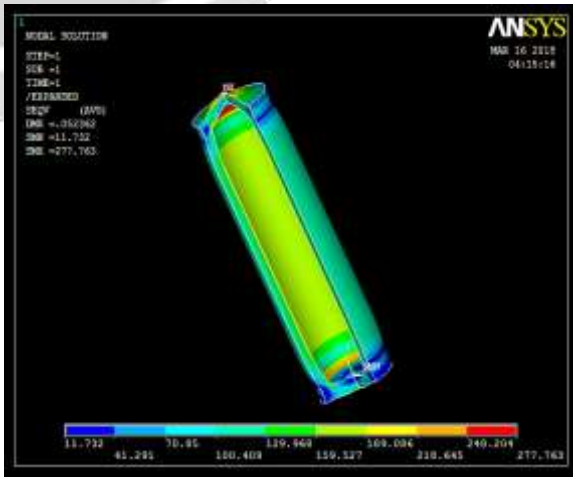

Fig -4: Stress distribution on cylinder body

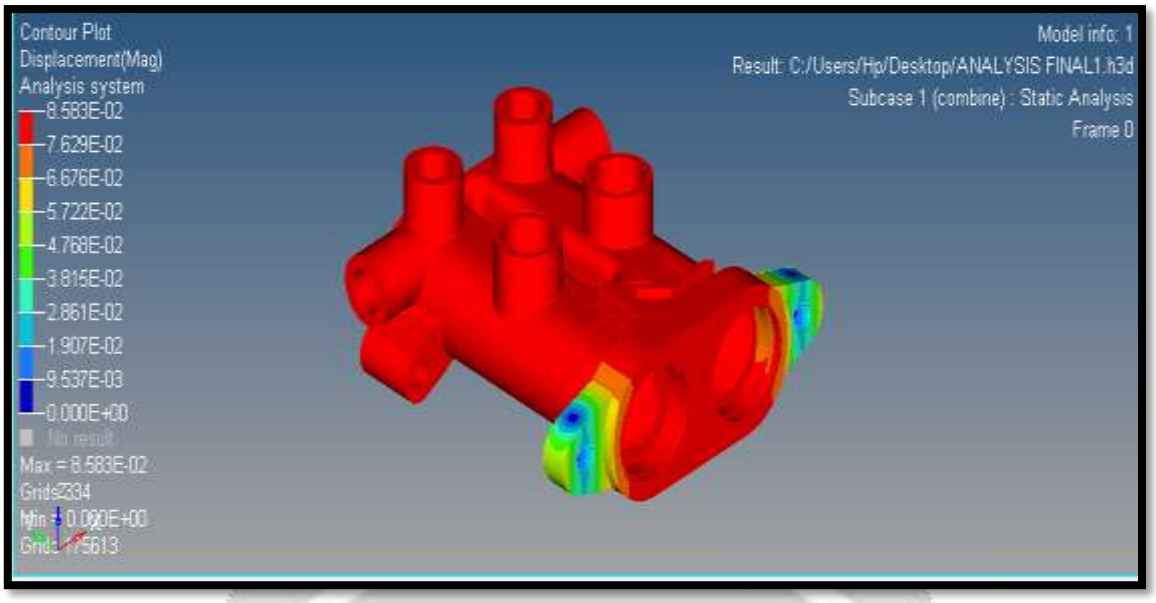

Fig -5: Displacement of integrated cylinder body

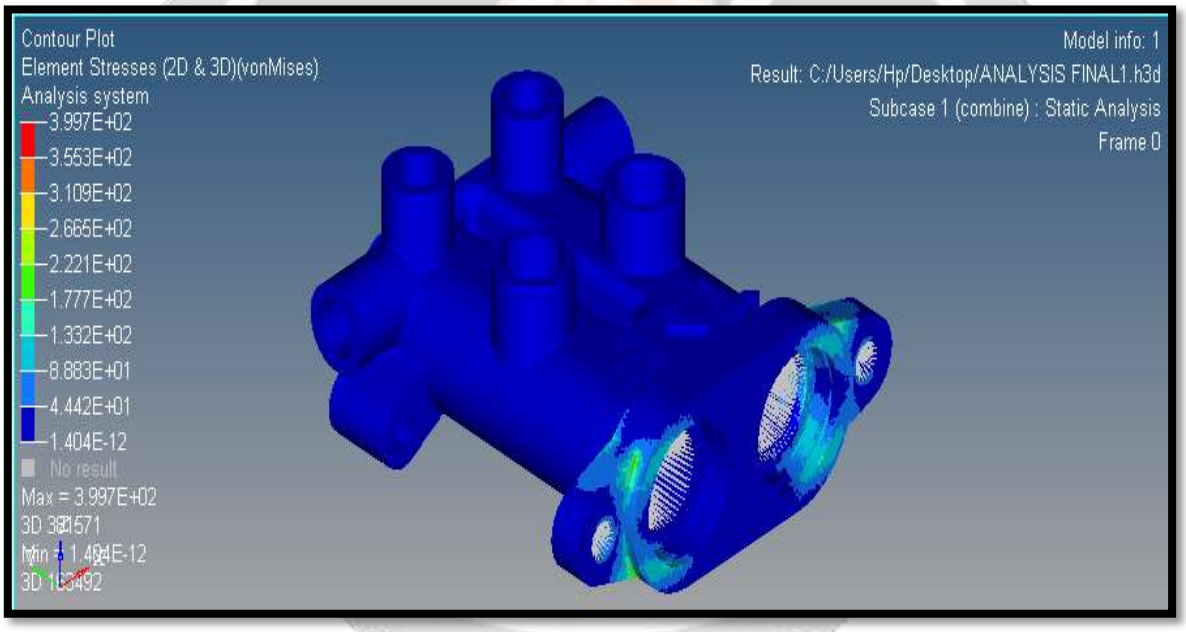

Fig -6: Stress on integrated cylinder body

Result:

- At the value of maximum pressure (worst condition) the maximum displacement is 0.0518 mm.
- Maximum stress generated in a cylinder body is 248.204 MPa. We know that the yield tensile strength of the Aluminium 6061 is 276 MPa. So the factor of safety for the cylinder body (FOS) is 1.113.

5. MANUFACTURED IMAGES

Fig -7: cylinder body

Fig -8: Piston (Spool)

Fig -9: Input caps

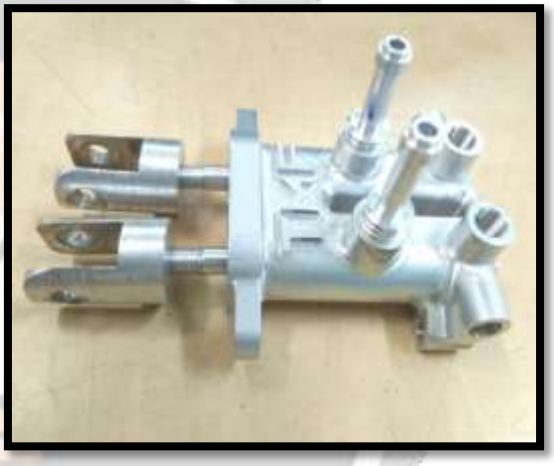

Fig -10: Assembly of master cylinder

6. TESTING VALUES

Iteration	Testing Speed (kmph)	Designed braking distance (m)	Actual braking distance (m)
1	40	4	4.2
2	40	4	4.3
3	40	4	3.8
4	40	4	3.9
5	40	4	3.5
6	40	4	4.1
7	60	4	4.4

8	60	4	3.9
9	60	4	3.9
10	60	4	4.3
Average	50	4	4.03

Table -1: Braking Distance – Testing Values

7. CONCLUSION

All results were verified by testing of the vehicle.
Thus, we can conclude that the designed and manufactured Twin Integrated Hydraulic Master Cylinder satisfies all the requirements as it has been verified by testing.

8. REFERENCES

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