International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 12 | Dec 2019 www.irjet.net p-ISSN: 2395-0072

DESIGN, MANUFACTURING AND TESTING OF TRANSPARENT ACRYLIC PROTOTYPE OF HYDRAULIC BRAKE MASTER CYLINDER

AKASH KHAMKAR[1], ADITYA PACHUPATE[2], VINAYAK PATIL[3], SHUBHAM BADGUJAR[4]

[1,2,3,4]*Student, Dept. of Mechanical Engineering, PCET's Pimpri Chinchwad College of Engineering, Pune, India*

Abstract – *Safety has a prime importance in day to day life. Since, hydraulic brakes are the best safety feature for the vehicles; they are used in almost every vehicle available today on the road. Master cylinder is used to generate the hydraulic pressure inside the brake lines to apply the brakes. The purpose of this paper is to propose solution for testing the hydraulic brake master cylinder in an efficient way. This paper presents transparent acrylic brake master prototype as an efficient solution to analyze dynamic working of brake fluid inside the master cylinder and to evaluate failure causes leads to brake fluid leakage through the oil seals.*

Key Words: **Hydraulic brakes, master cylinder, acrylic, prototype, testing, bleeding process**

1. INTRODUCTION

Braking system is an energy converting system which converts vehicle movement into heat while stopping the rotations of wheel. Generally, hydraulic brakes are used in every vehicle on the road where hydraulic pressure is used to create braking force on the brake disc which causes friction between brake pads and brake disc and vehicle stops. The brake master cylinder is hydraulic cylinder which generates pressure when pedal force is applied by the driver on the brake pedal. Since, we cannot see the dynamic working of piston and brake fluid inside the master cylinder, one cannot suggest the causes of seal wear and accumulation of air bubbles inside the cylinder. Hence, transparent acrylic cylinder body is proposed as the best solution to analyse and evaluate basic causes during the working of the brake master cylinder.

2. MASTER CYLINDER

A brake master cylinder is a central pressure pump. It uses force generated by mechanical advantage of the brake pedal which is further converted into hydraulic pressure by compressing brake fluid inside the brake lines. The brake lines are connected to a master cylinder for transportation of pressurized fluid from master cylinder to the brake caliper where it pushes caliper piston and thus brake pads against the brake rotor which causes friction and vehicle stops. It has fluid inlet and compensating port connected to a brake fluid reservoir which supplies brake fluid into the cylinder when vacuum gets created inside the master cylinder. When the brake pedal is applied by the driver, the brake fluid in system gets compressed and brakes are applied. Further when brake pedal is released the piston moves backward due to the compression spring.

The process flow chart of the master cylinder is given as follows:

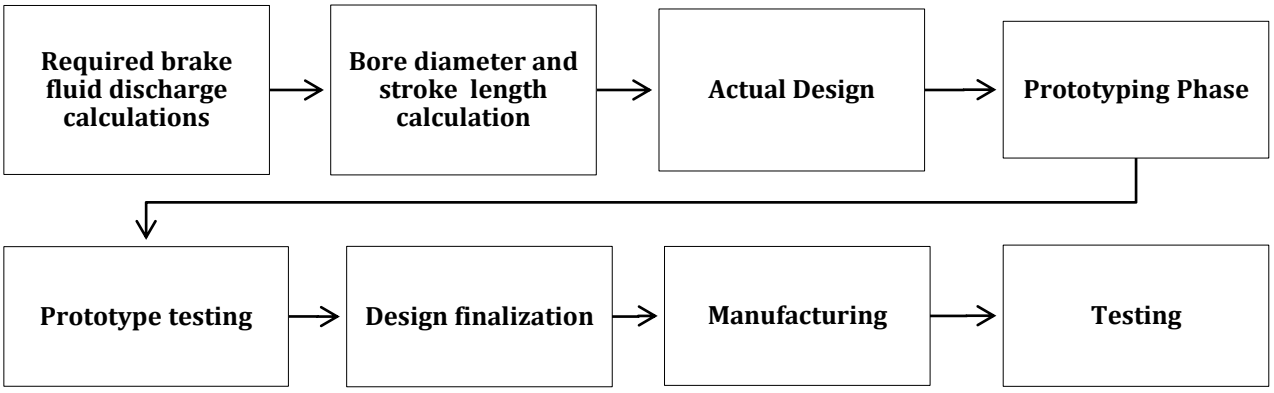

Fig -1: Process flow chart of master cylinder

2.1 Required brake fluid discharge calculations

As master cylinder is central pumping cylinder, it needs to pressurize fluid required by all four brake caliper at four wheels. Generally, caliper seal retraction is taken between 0.4 to 1mm. For calculating master cylinder bore diameter and stroke length the maximum caliper seal retraction is taken as 1mm. Fluid discharge calculations are done by using following data:

- Caliper piston diameter = d
- Caliper seal retraction = *l*
- Number of caliper pistons = n
- Master cylinder stroke length = L

Volume of brake fluid displaced by brake calipers = $((\pi/4) \times d^2 \times n \times l)$ [1]

Considering seal availability and seal material the master cylinder bore diameter is selected as D mm.

Volume of brake fluid displaced by brake caliper = $((\pi/4) \times D^2 \times L)$ [2]

By equating equation [1] and [2], we can find out what is the minimum required stroke length of the brake master cylinder to lock all four wheels.

2.2 Design of master cylinder

The Brake master cylinder is a piston cylinder assembly in which input force is provided by the mechanical advantage of the brake pedal and output is taken as hydraulic pressure which is used to push the brake pads against the brake disc to stop the wheel rotations. Following are the components of the brake master cylinder:

- Master cylinder body
- Piston
- U cup oil seals
- Retraction spring
- Pushrod

1) Master cylinder body - Above components are designed by using CATIA V5 and UG NX 10.0 3D modeling software. The master cylinder body is designed in such way that it has one inlet and one compensating port which is connected to brake fluid reservoir by using rubber hose. Further, it has two fluid outlets which will provide the compressed brake fluid to the front wheel brake calipers.

2) Piston with seals - The function of the piston is to generate hydraulic pressure using brake pedal force as input force. It is made up of Aluminium material with two EPDM (Ethylene Propylene Di-Methylene) U cup seals for compressing the brake fluid.

3) Retraction spring – It is a simple compression spring placed ahead of piston in the master cylinder. It gets compress when brake pedal is applied and relieves when brake pedal is released.

4) Pushrod - It is a simple steel rod which transfers force applied by the mechanical advantage brake pedal to the piston inside the master cylinder to create hydraulic pressure.

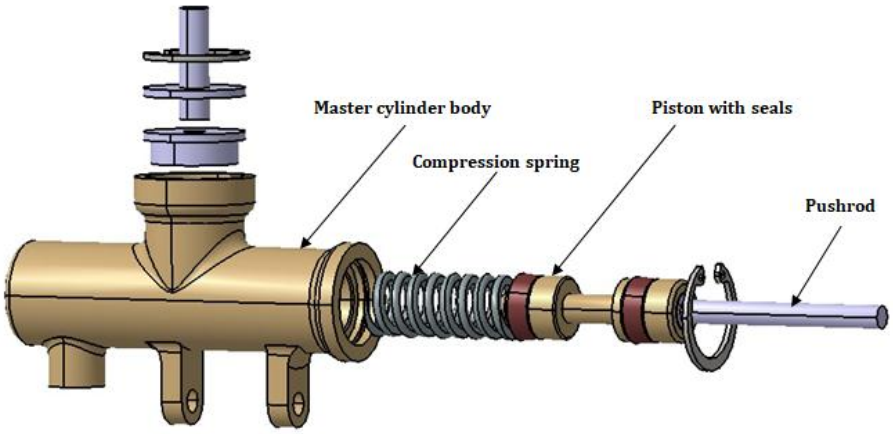

Fig -2: CAD model of master cylinder

3. PROTOTYPE MANUFACTURING

The master cylinder body prototype is useful to analyze dynamic working of brake fluid and causes for seal wear while working. Master cylinder body, piston and pushrod are manufactured while spring is brought as a OEM component. The following processes are used for manufacturing the prototype as shown in fig below.

Material used:

1) Master cylinder body - Acrylic block

2) Piston – Aluminium

3) Pushrod – Mild steel

Manufacturing process used:

1) Boring – The cylinder bore manufactured by using vertical machining center VMC boring tool to achieve fine surface finish.

2) Drilling - The mounting slots and fluid outlet ports are manufactured by using vertical machining center (VMC) drilling operation.

3) Threading – Threading operation is done at brake fluid outlets to attach brake line connectors.

4) Lathe turning – Piston and pushrod are manufactured by using turning operation on lathe machine

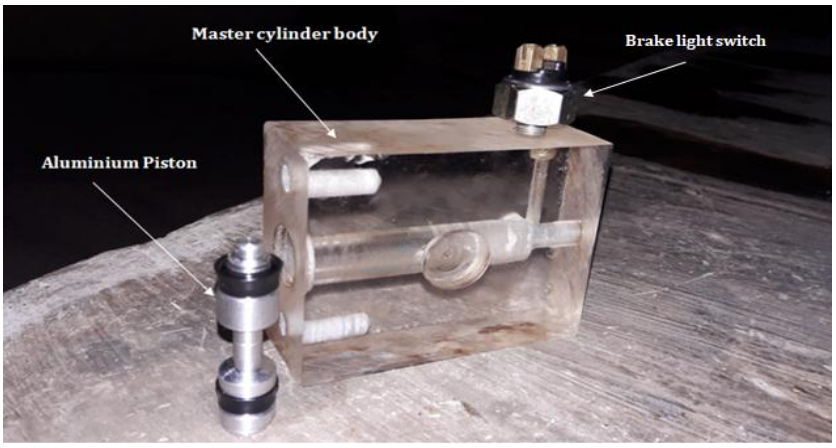

Fig -3: Acrylic master cylinder prototype

4. PRTOTYPE TESTING

Prototype testing is one of the important steps before finalizing the design. Basically, two conditions has been taken into consideration while testing the prototype in a right way. The main aim behind the prototype testing is to check what are the chances of air bubbles accumulation inside the cylinder body and causes of oil seals wear during dynamic working of the master cylinder. The testing is conducted by mounting the master cylinder prototype on a chassis with connected brake lines and brake caliper to check wheel locking when brake pedal is applied. Following conditions are taken into consideration while testing the acrylic prototype for the intended purpose.

4.1 Seal wear for maximum pressure condition

As shown in the figure, the master cylinder prototype is mounted on the chassis of the vehicle using mounting holes. The mechanical pressure gauge is connected to the prototype for easy visuals of hydraulic pressure while applying the brake pedal.

Fig -4: Master cylinder prototype mounted on a chassis with mechanical pressure gauge

As seen from the above figure, the seal wear can be clearly seen for maximum fluid pressure for a specific period of time. The causes of seal wear can be easily analyzed by seeing from the top surface of the acrylic prototype. Change in brake fluid colour is also the sign of oil seal wear which can be judged easily during the time of testing.

4.2 Dynamic behavior of air bubbles during bleeding process

This testing is done to check dynamic behavior of air bubbles inside the master cylinder during bleeding process. Bleeding is a process of removal of air bubbles inside the brake lines to efficient hydraulic pressure generation when brake pedal is applied by the driver. Following are the causes for air bubbles accumulation:

1) T-joint at outlet ports

2) Twisting of brake lines

3) Position of brake light switch

4) Brake fluid discharge rate

Above factors also affects bleeding time. The air bubbles movements can be easily tracked during the testing period. The following figure shows easy interpretation of air bubbles and their cause of accumulation inside the cylinder. The air bubbles removal process from the master cylinder circuit by continuously pressing the brake pedal is called as bleeding. During bleeding process some of the oil is extracted through brake caliper to remove air along with brake oil. When vacuum gets created due to removal of brake oil, oil from reservoir fills the cavity inside the master cylinder and process continues till all the air bubbles gets eliminated from the brake lines.

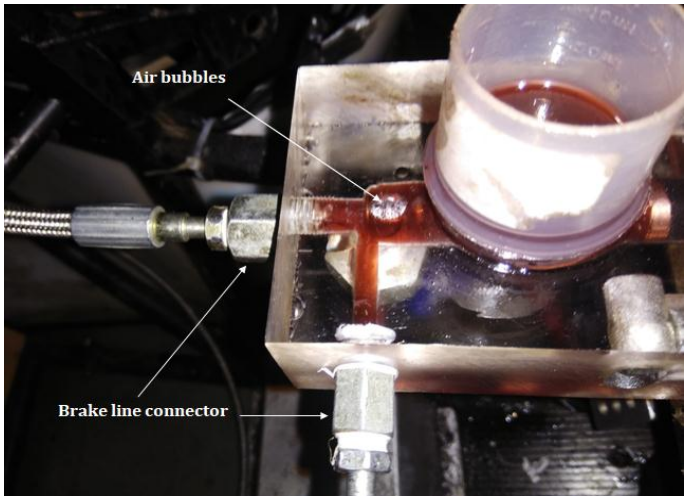

Fig -5: Dynamic behavior of air bubbles during bleeding

5. CONCLUSION

The testing of master cylinder prototype can be done easily, accurately and efficiently by using acrylic prototype for outer cylinder body. As seen before, the seal wear can be easily analyzed by seeing brake fluid colour and air bubble entry through the oil seals during working of the master cylinder. Also, one can easily find out the causes of air bubbles accumulation inside the master cylinder body by changing different brake parameters. The transparency of acrylic material is the main source of selecting acrylic as a prototype material for the outer cylinder body. The ease of manufacturing makes the testing more easier in a short period of time. As there are no chances of wear of tear of acrylic material at highest fluid pressure condition it is one of the reason for selection of specific acrylic material. From testing results, we find that bottom position of brake light switch can use of solid brake lines where there is no chance of twisting reduce chances of air bubbles accumulation inside the cylinder body. Also, we analyzed seal behavior for different seal material like EPDM (Ethylene Propylene Di-Methylene) and PU (Polyurethane). Therefore, it is easy selection process of oil seals and parameters like position of brake light switch, selection of brake lines and other causes of air bubble accumulation while finalizing the master cylinder design.

REFERENCES

[1] Rudolph Limpert, “Brake design and safety,” 2nd Edition, Society of Automotive Engineers Inc. Warrendale, Pa.

[2] Fred Puhn, Brake handbook, HP Books 1985

[3] “U Cup selection guide,” Hi-Tech Seals Inc.