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Design and analysis of the hydraulic braking system in the master cylinder

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Abstract:

The hydraulic brake system's master cylinder is nothing more than a piston on the inside of a cylinder. Braking is initiated and controlled by the master cylinder, which is the most important component of the braking system. Several braking fluid reservoirs are coupled to the Master Cylinder, which serves as the primary reservoir. It's a single layer of material that forms the reservoir and the cylinder of a master cylinder. It is the goal of this study to reduce weight to boost fuel efficiency in conventional road vehicles and also increase vehicle speed in sports cars. We can save some kilos just at the end of a design by reducing grams in various areas of an automobile. The master cylinder can be made of plastic because it has sufficient elasticity and is sturdy enough. The master cylinder's weight is reduced because of the use of polymers in its construction. PRO-E is used to model the master cylinder, and the ANSYS workbench is used to conduct the study. PRO-E and ANSYS make it simple to model and analyze automotive components like master cylinders.

Keywords:

Polymers, Brake fluid, Pro-E, Main piston, Fluid reservoirs, Master Cylinder, ANSYS.

1. Introduction:

All other parts of the brake system are supplied by the master cylinder, which transfers hydraulic pressure. The brake fluid is the most critical in your automobile, and this container houses it (Winterbottom, 1970). The brake pedal activates two distinct subsystems, one of which controls the other. This is to ensure that even if one system has a large leak, the others will continue to work (Yang, Li, and Long, 2013). All other parts of the brake system are supplied with hydraulic pressure by this master cylinder. The braking fluid is stored in this compartment. The brake pedal activates two distinct subsystems, one of which controls the other. This is to ensure that even if one system has a large leak, the others will continue to work (Toensmeier, 2016). Two distinct fluid reservoirs may be used, or a single shared reservoir may be used. Front/rear braking subsystems are common, as are diagonally-separated ones. The "main piston" in the master cylinder pushes forward when the brake pedal is pressed. One of two subsystems is activated when the primary piston is depressed. Hydraulic pressure and the spring force of a primary piston drive this secondary piston forward. Hydraulic pressure increases in the wheel cylinders when the pistons move forward and their primary cups block the bypass holes.

1.1 Aim

With ANSYS, this project aims to design and analyze Hydraulic Braking System Master Cylinder. As well as testing the entire brake system's operation.

1.2. Objective

- In the case of conventional road vehicles and sports automobiles, this is done to boost the vehicle's speed and mileage.
- Focus on lighter brake master cylinders through material substitutions.
- To conceal the holes in the bypass.
- To keep tabs on the fluid levels in the reservoirs.

1.3. Research Question

1. Why Master cylinders are designed to last a long time?
2. Brake Master Cylinder Problems: What are the Signs?

3. Is it possible to fix master cylinders?

2. Literature Review:

2.1. Master cylinder:

The hydraulic brake system's master cylinder is nothing more than a piston from the inside of a cylinder. Braking is initiated and controlled by the master cylinder, which is the most important component of the braking system. The braking fluid is stored in a reservoir linked to the master cylinder (Bagytzhan, Zhagypar, and Kukkuzova, 2019). The reservoir and cylinder of a master cylinder are made of a single piece of molded material. They are called master cylinders. A master cylinder is nothing more than a piston housed inside a cylinder in a hydraulic braking system. Braking is initiated and controlled by the master cylinder, which is the most important component of the braking system. Several braking fluid reservoirs are coupled to the Master Cylinder, which serves as the primary reservoir. A single-piece molded-material master cylinder with a reservoir as well as a cylinder (Berghel, 1995).

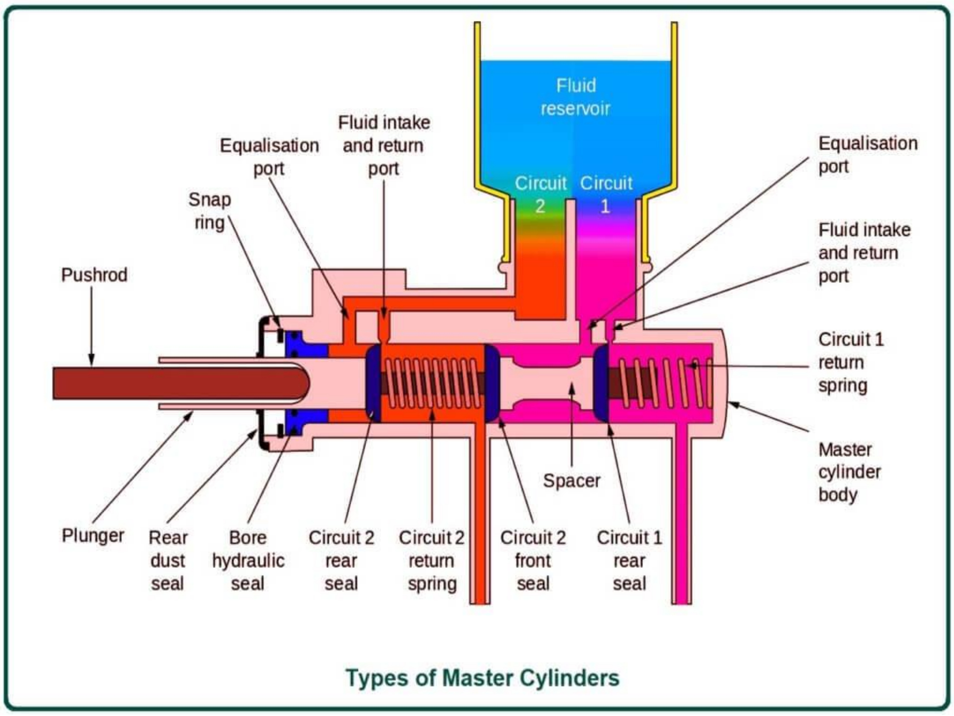

Figure.1: Master cylinder sectional view [source: (Berghel, 1995)]

2.2. Working of master cylinder:

There is a small gap between the intake port and compensatory port when no brakes are applied, which is why they are called "piston cups." Connecting the cylinder to the reservoir tank needs to be done. The secondary return spring pushes the secondary piston to the right, but a stopper bolt prevents it from going any further. A leftward movement of the primary piston is caused by depressing the brake pedal" (Weber, Mund, Leidermann, and Zink, 2004). The compensating port is sealed by the piston cup, which prevents air from escaping from the reservoir tank into the primary pressure chamber. Cylinder-to-wheel hydraulic pressure is built up and transmitted when the piston pushes further into its chamber. The secondary piston receives the same hydraulic pressure. The secondary piston is also moved to the left by hydraulic pressure in the first chamber. Fluid pressure accumulates in the secondary chamber once the compensating port is closed, and this pressure is transmitted to a secondary winding (Weber, Mund, Leidermann, and Zink, 2004).

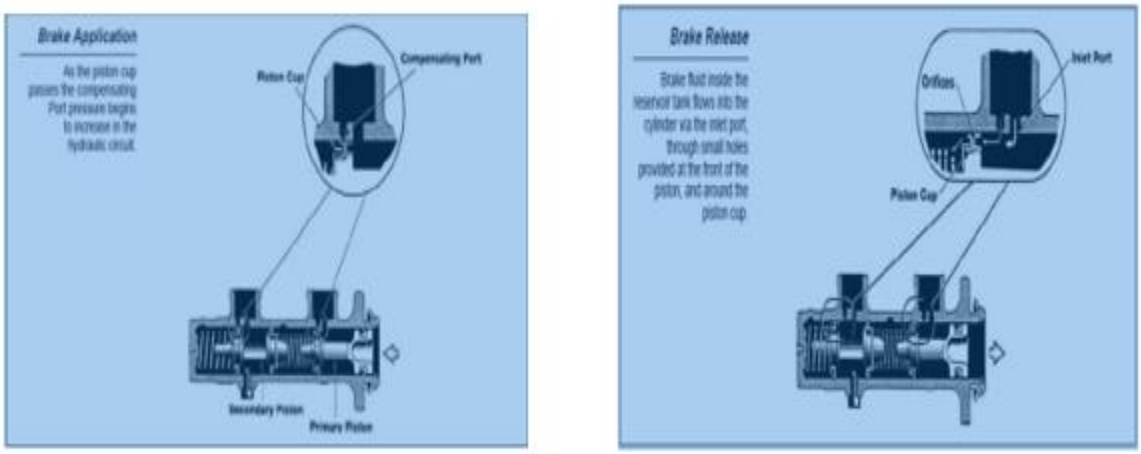

Figure.2: Working of master cylinder-brake application and working of master cylinder-brake release [source: (EL AZIZI, 2019)]

2.3. Design considerations of master cylinder:

The basic information regarding the braking system as well as its master cylinder, its function, purpose, operating principle, different size and shapes of the master cylinder, and failure considerations has already been collected from the automobile brake system. When it comes to older cars and trucks, braking system components makers report that cast iron cost mold brake cylinders were the standard. Since then, there has been an uptick in a study into lighter vehicles and how to improve mileage. Composite master cylinders with an aluminium-and-plastic-material reservoir have been developed by the makers, resulting in a lighter master cylinder compared to the more expensive cast iron mold master cylinder. To reduce the weight of master cylinders, certain manufacturers are modifying the materials and methods of production.

2.4. Polypropylene:

Polypropylene can be used in a wide range of applications. Its lightweight, strength, heat resistance, stiffness, and flexural retention make it an excellent material for a variety of applications. Polypropylene has a wide range of advantages, including the fact that it may be easily molded (Mikhailov, Tokareva, and Popov, 1963). Polypropylene can be made in a variety of ways and used in a variety of ways. It's a thermoplastic polymer utilized in a wide range of applications, including vehicle parts, labeling and packaging and textiles, stationery, plastics parts, and reusable containers. Polypropylene is also known as polypropene.

2.5. Modeling using pro-e:

An application called Pro/ENGINEER (Pro/E) is used to build precise 3D computer models. Solid modeling is used to produce 3-D models using Pro/E. (as opposed to a wireframe or surface modeling). The terms "feature-based," "associative," and "constraint (or parametric)-based" are also used to describe Pro/E. (Kobzov et al., 2020). Fully parametric, Pro/E is an excellent CAD package For example, holes and slots on a part must be specified in terms of their size, form, orientation, and position. This means that now the geometry of all characteristics on a part must be properly documented. An equation (i.e., a relation) can be written to define how characteristics of different components (or multiple parts) relate to one another in this specification.

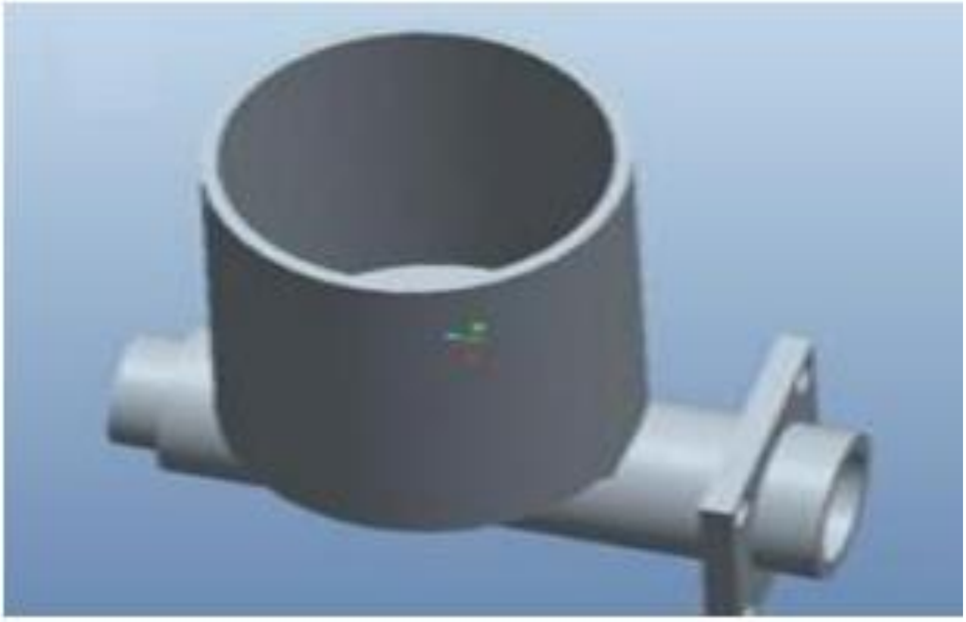

Figure.3: Designed model in pro-E [source: (DOSZHANOV et al., 2020)]

3. Research Methodology:

For this study, we used secondary data that was gathered from a variety of sources including published articles and books, as well as articles from scholarly journals and websites.

3.1. Data acquisition:

For the sake of data analysis, the finite method has made use of this method. The finite element method (FEM) is a computational tool for solving partial differential equations and functional minimization problems (EL AZIZI, 2019). There are finite elements that make up a particular domain. The nodal values of such a physical field are used to determine approximate functions in finite elements. A discretized finite element issue having uncertain nodal values is created from a continuous physical issue. There must be an algebraic solution to a linear issue. Nodal values can be used to retrieve the values of finite elements. The energy functional of every finite element model can be minimized by using the finite element method (EL AZIZI, 2019). The derivative of a function concerningan unknown grid point prospective is set to zero to find the functional's minimum.

These are the technical characteristics of a standard cylinder utilized in this research.

NAME	SYMBOL	UNITS	DIMENSION
RESERVOIR OUTER DIAMETER	D_o	mm	75
RESERVOIR INNER DIAMETER	D_i	mm	69
THICKNESS OF RESERVOIR	T	mm	3
HEIGHT OF RESERVOIRS	H	mm	88
CYLINDER OUTER DIAMETER	d_o	mm	33.4
CYLINDER INNER DIAMETER	d_i	mm	25.4
THICKNESS OF CYLINDER	t	mm	4
HEIGHT OF CYLINDER	h	mm	148.5

Figure.4: Specifications for cylinder [source: (EL AZIZI, 2019)]

3.2. Data analysis:

Finite element analysis gets all desired unknown model parameters by minimizing an energy function. The finite element model's energy function includes all of these energies. A finite element power function has to be zero because of the conservation of energy (EL AZIZI, 2019). Finite element analysis' basic equation is:

$$\partial f / \partial p = 0$$

There are two variables in this equation: F and p, which represent the unknown grid cell potential (in mechanics, potential displacement). A particle's virtual work is 0 for any displacement if it is in equilibrium with a constant force, according to the principle called virtual work. Each finite element should have its tremendous energy function (Kobzov et al., 2020).

MATERIAL	YOUNG MODULUS	POISSON'S RATIO
ALUMINIUM	70000 N/mm^2	0.3
POLYPROPYLENE	2000 N/mm^2	0.28

Figure.5: properties of materials [source: (Kobzov et al., 2020)]

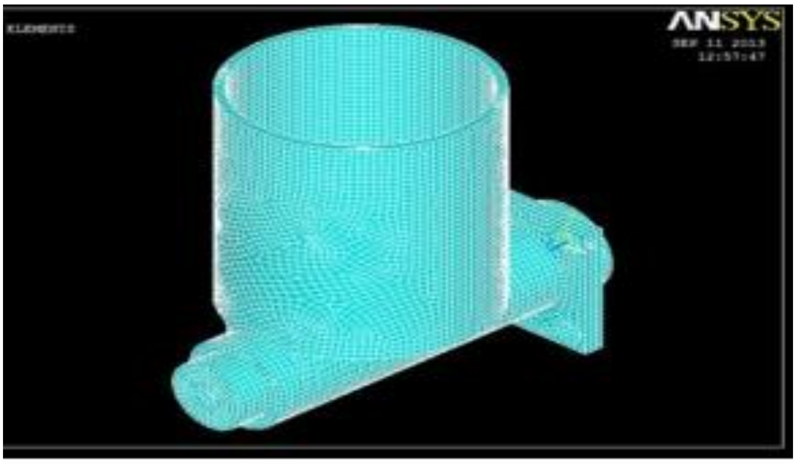

Figure.6: Meshed model for brake master cylinder [source: (Cranmer, 2018)]

4. Results and Discussion:

2.25953 N/mm2 is the maximum stress on the polypropylene cylinder surface with a pressure of 3.95 N/mm2, which is roughly equivalent to 4 N/mm2. The maximum stress on the aluminium master cylinder surface, which is 1.67259 N/mm2, is slightly lower. Polypropylene can sustain the pressure because the greatest stress occurring on the cylinder's surface is very low compared to the ultimate strength of the material.

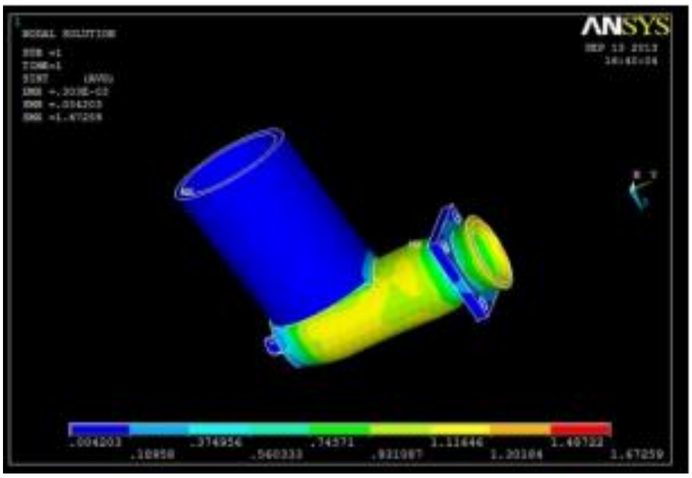

Figure.7: Stress intensity on the aluminium master cylinder

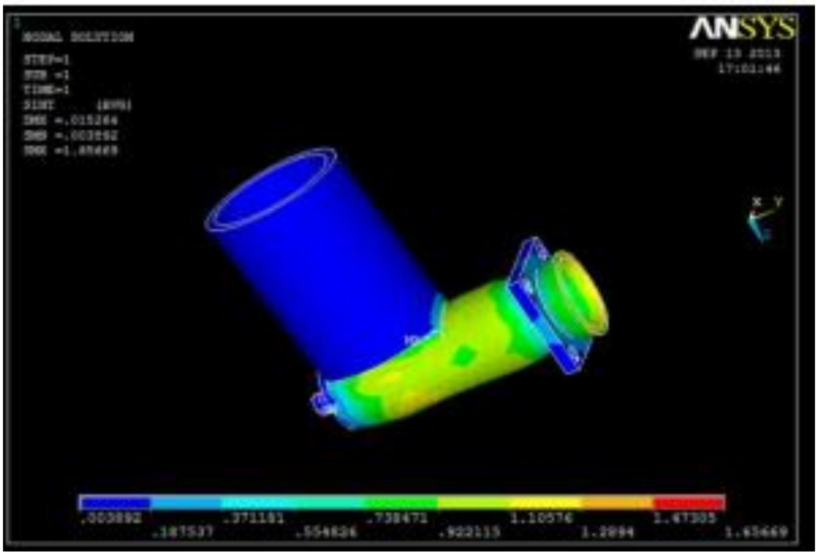

Figure.8: Stress intensity on Polypropylene master

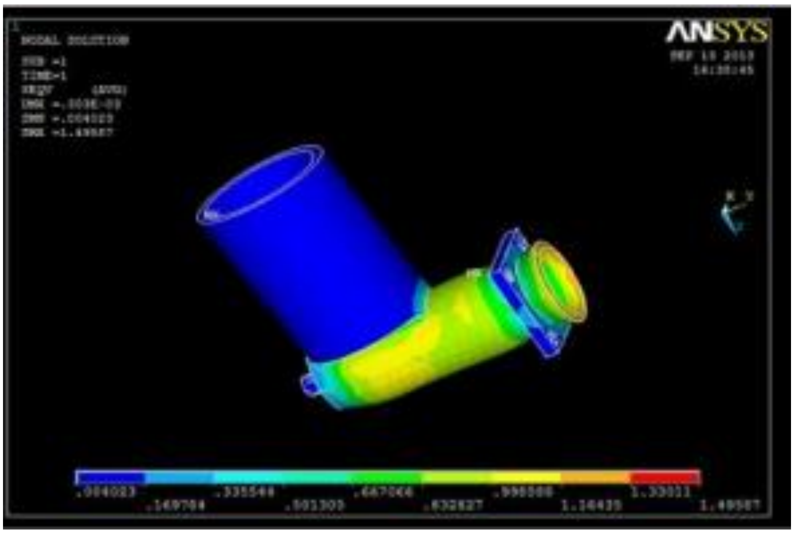

Figure.9: Stress on the Aluminium master cylinder

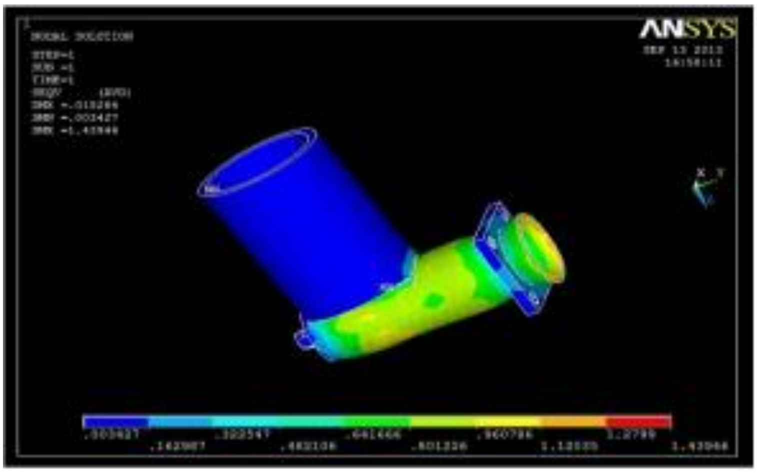

Figure.10: Stress on polypropylene master cylinder

5. Conclusion:

To come up with the model, designers used calculations that were oriented toward the design. Based on an investigation into the use of ANSYS for modeling and analysis. Plastic and aluminium master cylinders are designed and analyzed in this project. This means that plastic master cylinder offers even more benefits to automobiles. Polypropylene's 0.124-kilogram master cylinder weighs less than Aluminium's 0.355 kg master cylinder, according to the findings. Polypropylene master cylinders are subjected to more stress than aluminium master cylinders, however, the stresses created in polypropylene master cylinders are much lower than the ultimate strength of the material.

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Cite as

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