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Design and Analysis of Plastic Brake Master Cylinder for Automobiles

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Abstract: In the entire hydraulic braking system master cylinder is the key element, which initiates and controls the braking action. The master cylinder consists of reservoir to store brake fluid. Due to the behavior of fluid in a closed system force applied from the brake pedal is transformed into pressure, which is distributed to the brake units through brake lines. Since pressure inside a closed system is equal in all the area, pressure distributed from the master cylinder is equal throughout the brake system. A master cylinder having a reservoir and a cylinder formed from a single piece of molded plastic. The present paper is about designing of Plastic master cylinder and doing a feasibility study of its strength using ANSYS. This design is based on the most important challenge that automotive industry is facing now. The project is on reducing weight which is one of the factors to increase the efficiency. The design of plastic master cylinder is carried using CATIA where as the analysis of its strength is done using ANSYS.

Index Terms—**Plastic brake master cylinder, Automobiles, Saving of grams at different parts, Ansys, Catia.**

I. INTRODUCTION

Maximizing of vehicles performance is achieved by strict weight reduction. Making the car lighter will improve the vehicle's handling and performance. There are three ways to make a car go faster and quicker in racing technology: add power, remove weight or both. Having a light weight racing car is more advantageous since its parts doesn't brake like in case of heavy weight vehicle. And also a car with minimum accompaniments makes it easier to maintain. Even though it is more advantageous but the main concern is vehicle handling and performance which can be achieved through weight reduction. There has been many a component or body panels that have been replaced by lighter materials by years and one of the components which can also be considered to make it light weight by changing the material is brake master cylinder.

II. LITERATURE REVIEW

Lane Eichhorn, Clifton E Owen, Ken Layne, Jack Erjavec,2001(9) presented, In all the vehicles brake system was controlled by single master cylinder until 1967, after the several manufacturers added dual tandem master for the better safety of the vehicle. The diagonally split Hydraulic master cylinder was introduced by Daimlerchrysler in 1978, which is significantly used all the vehicles now a days. James D.Halderman, 1996 (8) presents the construction using two different materials. The body is made of aluminum and plastic materials are used for reservoir. C. J. Buynacek and W.L.Winterbottom(2) High Volume Semi-Solid Forming of Aluminum Master Cylinders (2000-01-0060) written by C.J.Buynacek and W.L.Winterbottom, features the design and development of semi-solid metal aluminum master cylinder for vehicle applications. It also helps *to continue further research on reducing the weight and improves the design by changing the material and also helps on concentrating reduction of manufacturing cost through different technology such as injection moulding.* Rosé Nash (15) explains Brake Integrated Hydraulic Actuation System Mater Cylinder written by Roscoe Nash explains about the design and operation of new stepped bore master cylinder. Lightweight Brake System written by Jeri S. Culp (3) features numerous innovations and it has been developed mainly for the purpose of highway and recreational vehicle use. In Automobile Weight Reduction Using High Performance Plastics written by Richard F. Waughtal (17) explains about how to achieve high performance through weight reduction. Since reduction of weight in the vehicles is the major factor which can be achieved by replacing metal components with lighter weight, multifunctional plastics and composites. Before replacing metal components with plastic, it has to undergo certain necessary conditions which involve bearing loads, moving contact speeds and temperature. Wildwood disc brakes has engineered and manufactured the new brake system which describe the custom after market and dominate professional motorsport in USA over past 30 years.

III. MATH

Basic formulation of Finite Element Equations (static Analysis) In the following section displacement method or the principle of minimum potential energy is used. Principle of minimum potential energy of an elastic body πp is defined as:

A. $\pi p(u,v,w) = 1/2\iiint \varepsilon 2\ [D]\ (\varepsilon - \varepsilon 0)dv - \iiint \Phi T\ U.dv - \iint \varphi\ T\ U.dS1$

Where

$$\Phi \begin{Bmatrix} \Phi x \\ \Phi y \\ \Phi z \end{Bmatrix} = \text{known body force vector,}$$

$$\varphi = \begin{Bmatrix} \varphi\ x \\ \varphi\ y \\ \varphi\ z \end{Bmatrix} \quad \text{is vector of prescribed surface}$$

Forces (Tractions), U = $\begin{Bmatrix} u \\ v \\ w \end{Bmatrix}$ = vector of displacements and S1 is the

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Surface of the body on which surface forces are prescribed. The displacement model within an element "e" is assumed as

$$U = \begin{Bmatrix} u(x, y, z) \\ v(x, y, z) \\ w(x, y, z) \end{Bmatrix} [N] * Q(e)$$

Where Q(e) is the vector of nodal displacement degrees of freedom of the element and [N] is the matrix of shape functions.

IV. UNITS

Plastic Master Cylinder with Weight
Reservoir outer diameter Do = 75mm
Reservoir inner diameter Di = 69mm
Thickness of Reservoir, t = 3 mm
Height of Reservoir H = 88 mm
Cylinder Outer Diameter Do = 33.4 mm
Cylinder Inner Diameter Di = 25.4 mm
Thickness of Cylinder t = 4 mm
Height of Cylinder H = 148.5 mm
Density d = 1200 m3

V. HELPFUL HINTS

A. *Figures and Tables*

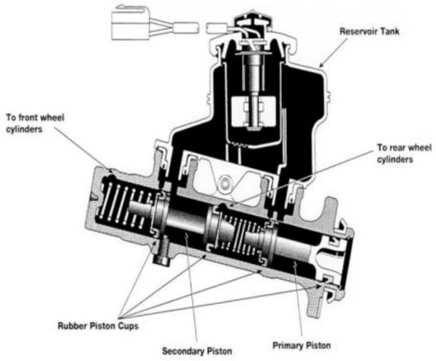

Fig 1. Sectional view of Brake Master Cylinder

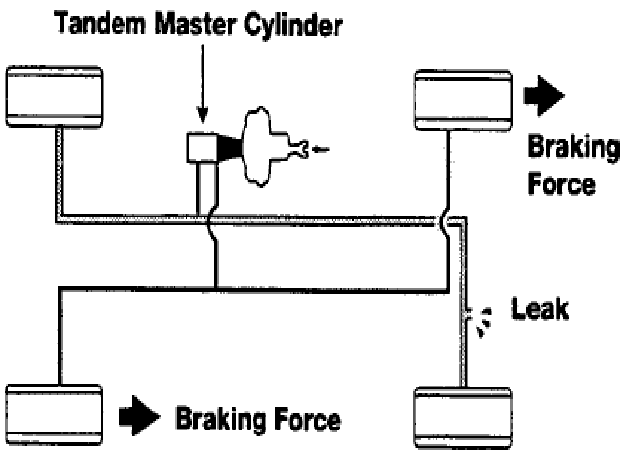

Fig 2: Diagonal Piping

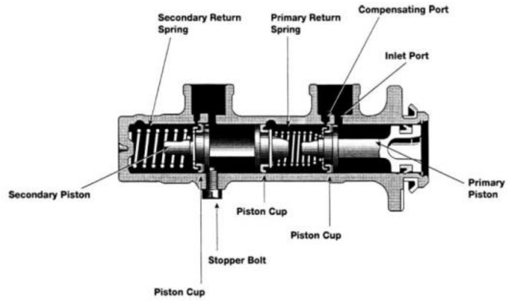

Fig 3: Master Cylinder Components

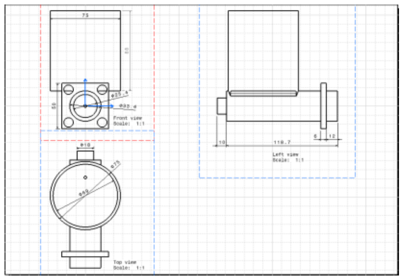

Fig 4: Detailed View of Plastic Master Cylinder

Table 1 Materials Temperature

S.NO	MATERIAL PROPERTIES	VALUES
1.	Thermal conductivity	190 W/MK
2.	Specific heat	880J/KGK
3.	Density	0.0000027 Kg/m^3

Table 2. Specifications for Cylinder

yName	Symbol	Units	Dimension
Reservoir Outer diameter	Do	mm	75
Reservoir Inner diameter	Di	mm	69
Thickness of Reservoir	t	mm	3
Height of Reservoirs	H	mm	88
Cylinder outer diameter	do	mm	33.4
Cylinder inner diameter	di	mm	25.4
Thickness of Cylinder	t	mm	4
Height of Cylinder	H	mm	148.5

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Table 3; Results comparison

Type of Cylinder	Mass in kg	Density kg/m3
Aluminum master cylinder	0.355	2710
Plastic master cylinder	0.157	1200

Table 4. TYPE OF ELEMENT

ELEMENT TYPE	DESIGN MODEL	TYPE OF ANALYSIS
Tet 10 node 187	ANSYS	Stress Analysis
Solid 20 node 90	ANSYS	Thermal Analysis

Table 5. Comparing the Results

MATERIAL	YOUNGS MODULUS	POISSON'S RATIO
Aluminum	70000 N/mm^2	0.3
Acetyl	2800 N/mm^2	0.35

Table 6. Properties of the Materials for Aluminum Master Cylinder from ANSYS

S.NO	MATERIAL PROPERTIES	VALUES
1.	Thermal conductivity	310 W/MK
2.	Specific heat	1500 J/KGK
3.	Density	0.00000223 Kg/m3

Table 7:. Material Properties for Acetyl Polymer Master Cylinder from ANSYS

MATERIAL	TEMPARATURE
Acetyl	UP to 700 k.
Aluminum	Up to 400 k.

Table 8: Load and stress values for Aluminum Master Cylinder from ANSYS

S.NO	LOAD	STRESS
1.	0	0
2.	0.962	0.661251

Table 9: Load and stress values for Acetyl Master Cylinder from ANSYS

S.NO	LOAD	STRESS
1.	0	0
2.	0.962	0.661251

Table 10: Minimum and Maximum Stress Values

Material	Minimum stress	Maximum stress
Aluminum	0	0.661251
Acetyl polymer	0	0.826358

Table 11: Temperature Values in Brake Master Cylinder

S.NO	TYPE OF TEMPARATURE	VALUES
1.	Thermal Temperature	453 K
2.	Bulk Temperature	318 K
3.	Film Coefficient	20 W/M2K

Table 12: Nodal Temperatures in Aluminum and Acetyl Polymer Master Cylinder:

Type of Material	Minimum Nodal Temperature (K)	Maximum Nodal Temperature (K)
Aluminum	317.949	453
Acetyl Polymer	317.925	453

Table 13: Thermal Gradients in Aluminum and Acetyl Polymer Master Cylinder:

Type of Material	Minimum Thermal Gradient (K/mm)	Maximum Thermal Gradient (K/mm)
Aluminum	15.4	1937
Acetyl Polymer	32.1	1762

Table 14: Thermal Fluxes in Aluminum and Acetyl Polymer Master Cylinder:

Type of Material	Minimum Thermal Flux (K/mm2)	Maximum Thermal Flux (K/mm2)
Aluminum	2.92	367.992
Acetyl Polymer	9.94	546.163

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IV. CONCLUSION

In this Paper the design and analysis of plastic and aluminum master cylinder are performed. And it is concluded that, the plastic master cylinder is more advantages for Automobiles. The following conclusions were made:

1) The weight of Master Cylinder made up of Acetyl Polymer i.e.0.157 Kg is less than Master cylinder made up of Aluminium i.e. 0.355 Kg.
2) The Master Cylinder made up of Acetyl Polymer material can bear more stress i.e.0.826358 N/mm^2 than master cylinder made up of Aluminium i.e. 0.661251 N/mm^2.
3) The Thermal flux in Master cylinder made up of Acetyl polymer i.e. 546.163 K/mm^2 is more than Master cylinder made up of Aluminium i.e. 367.992 K/mm^2. Thereby Heat transfer rate is good for Acetyl polymer than Aluminium.

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