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Design and Analysis of an Automotive Vacuum Suspended Power Brake Using Pro/MECHANICA®

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Absract **- The developments in automobile braking technology have attended new height. It is now to obtain greater braking effect in wheels, fail safe and more reliable braking system, and that to at much lower effort on the part of driver and by using same braking principle. These developments are mainly attributed to the power brake system in this article, an automotive vacuum – suspended power brake is analyzed using advance software. The goals of the structural analysis are to visualize the stress distribution, load application, deformation under static loads and validate the methodology used. The model predictions are shown to be in good agreement with analytical measurements. Predictions of forces, stresses on certain vacuum- suspended power brake components are taken from the existing system & compare with the FEA to ensure that excess wear can be avoided.**

Keywords **- FEA, Master cylinder, Vacuum booster, automobile, stress & Displacement analysis.**

I. INTRODUCTION

The demand for a reduction in brake pedal effort and movement, without losing any of the sensitivity and response to the effective braking of vehicles, has led to the adoption of vacuum booster assisted units as part of the braking system for most vehicles. These units convert the induction manifold vacuum energy into mechanical energy to assist in pressurizing the brake fluid on the output side of the master cylinder.

II. FUNCTION OF AN AUTOMOTIVE VACUUM SUSPENDED POWER BRAKE

An automotive vacuum suspended power brake system equipped with vacuum booster which consists of two chambers separated by a rolling diaphragm and power piston as shown in fig 1 .the power piston is coupled to the master cylinder outer primary piston by a power push rod. The foot pedal is linked through a pedal push rod indirectly to the power piston via a vacuum-air reaction control valve. Pushing down on the brake pedal releases vacuum on one side of the booster. The difference in air pressure pushes the diaphragm for braking action.

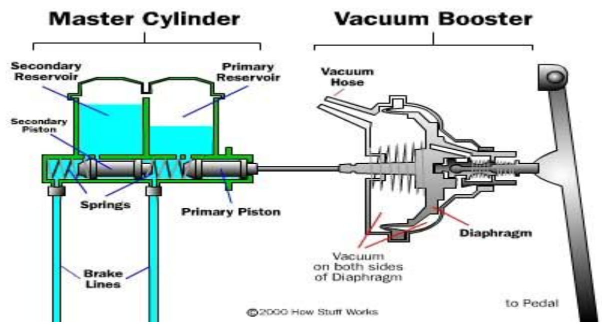

Figure. 1 An automotive vacuum suspended power brake

III. BASIC CRITERIA FOR DESIGNING A MASTER CYLINDER OF A POWER BRAKE

[Model -TATA-407 Cargo Movers]

A. *Force Input at brake pedal* = 10 kg = 100 N

B. *Force output at brake pedal*

Leverage of pedal =5

Force generated at the joint of the Foot Pedal = 5 x 100 =500 N

C. Force Increased due to Vacuum booster:

Pressure on one side of Vacuum Booster Diaphragm is Engine manifold = 0.55 kg/cm² and

Another side of the Diaphragm pressure is 1.03 kg/cm² [Technical Specification - TATA 407]

d=Diameter of vacuum booster piston.

D=Diameter of the vacuum diaphragm 203.20mm.

Area of Vacuum Diaphragm = $((\pi / 4) \times D^2) - ((\pi / 4) \times d^2))$

$= ((\pi / 4) \times 203.20^2) - ((\pi / 4) \times 50.80^2)$

$= 32429.28 - 2026.83$

$= 30402.45 \text{ mm}^2$

Force generating by piston due to atm. Pressure

F1 = Area of Vacuum diaphragm x Pressure

= A x atm. Pressure

= 30402.45 x atm. Pressure

= 30402.45 x 0.101315

= 3080.22 N

Force generating by piston due to vacuum Pressure

F2 = Area of Vacuum diaphragm x vacuum pressure

= A x vacuum pressure

= 30402.45 x vacuum. Pressure

= 30402.45 x 0.055

= 1672.13 N

Increase in the Force due to Vacuum:-

= F1- F2

= 3080.22 – 1672.13

= 1408.09 N

Total force acting on the Piston of the Master Cylinder = 500 + 1408.09 = 1908.09 N = 2002N=

D. *Design of the Master Cylinder:-*

Master cylinder oil pressure calculation. [Technical Specification - TATA 407]

Material of the Master Cylinder is Aluminum Alloys (cast).

According to IS designation material identify as a IS 4225 or BS LM16.

σ_u = 173 to 205 N/mm^2

Take the allowable tensile stress for aluminum cylinder is 0.4 x σ_u = 0.4 x 173

σ_t = 44.98 N/mm^2

By Considering the surface finish factor 0.9 and Factor of safety 2.0

So Tensile Stress for Master Cylinder Design Calculation

σ_t = 20.24 N/mm^2

Take, Master Cylinder inside Diameter.

di = 25 mm [Technical Specification - TATA 407]

Master Cylinder Force produced by Vacuum Booster W = 2002 N.

Pressure developed in the Master Cylinder

W = [(π/4) di² x p]

p = 4.08 N / mm^2

For safe side take the inside cylinder pressure is 10 to 20% of generated pressure.

So take the Inside cylinder pressure is p = 4.08 x 1.14 = 4.66 N/mm2 (Factor of safety)

IV. METHODOLOGY USED

The modeling and stress analysis of the vacuum suspended power brake has been done in Pro/ENGINEER Wildfire 3.0 and Pro/MECHANICA respectively, taking various constraints and boundary conditions. The necessary design modifications have also been made to rectify the problems being faced by the designer.

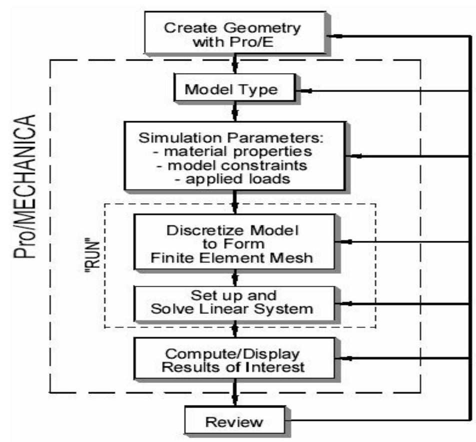

Figure.2 Problem solving approach

A. Constraints

There were various constraints or restrictions that were imposed by the designer.

- ✓ Material: - for master cylinder **"LM16"** having Density 2.79355e-09 tonne / mm^3, Young's Modulus 73084.4 N / mm^2, Poisson's Ratio 0.33, Ultimate tensile stress173 to 205 N/mm^2
- ✓ Type of power brake: - Type cannot be other than an automotive vacuum suspended power brake of TATA 407 Model.
- ✓ Internal Pressure: - There is uniform internal pressure acting in the power brake master cylinder system at 4.66 N/mm^2.

V. STRESS ANALYSIS FOR AN AUTOMOTIVE VACUUM SUSPENDED POWER BRAKE

The following steps are used for problem solving: -

A. Model Generation

Proper modeling of the parts is very important for getting accurate results of analysis. Creating the parts and its dimensioning scheme are important steps. The components of the shock absorber were modeled in the part mode of Pro/ENGINEER Wildfire 3.0. An automotive vacuum suspended power brake consists of the following part.

- ✓ Master cylinder
- ✓ Master cylinder piston

✓ Vacuum booster

These parts of an automotive vacuum suspended power brake are shown in following figures.

B. Assembly of an automobile vacuum suspended power brake

The assembly of all the components of an automotive vacuum suspended power brake was done in the assembly mode of Pro/ENGINEER Wildfire 3.0. The placement (or assembly) constraints were used to rigidly bind the components of power brake to their respective positions in the assembly.

The Assembly of a Vacuum Suspended Power Brake System is shown in following figure.

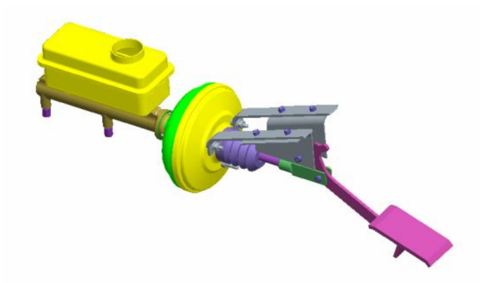

Figure3 Assembly of the vacuum suspended power brake system.

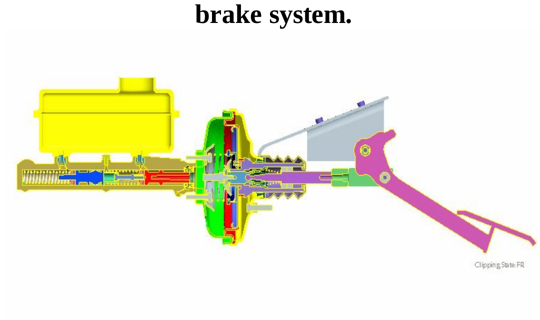

Figure 4 Cut section view of vacuum suspended power brake system.

The Assembly of the Master Cylinder –Piston is shown in following figure.

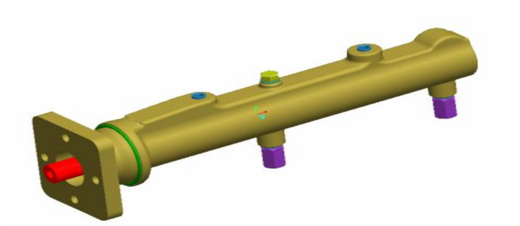

Figure 5 Assembly of the master cylinder.

Figure. 6 Explored View of the master Cylinder

The Assembly of the Vacuum Booster is shown in following figures.

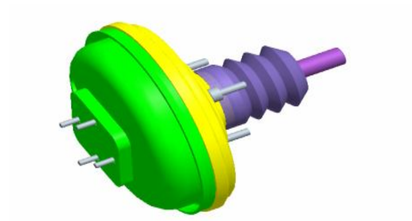

Figure. 7 Assembly of the vacuum booster.

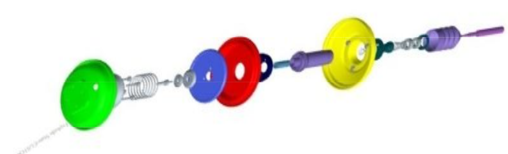

Figure. 8 Exploded view of the vacuum.booster

C. Static Structural Analysis

With the wide spread adoption of CAE approach to design, Finite Element (FE) analysis became integrated with the design and analysis procedure. Structural analysis is used to analyze parts and assemblies to find :-

- ✓ Maximum stresses
- ✓ Deformed Shapes (Deformation)

The analysis of a structure during its design process is accomplished by the solution of the partial differential equations that describes the given model.

D. Steps involved in carrying out analysis using Pro/MECHANICA

Pro/MECHANICA is a computer aided engineering tool that allows us to simulate the physical behavior of a part or assembly, to understand and improve mechanical performance of a design. It enables us to analyze and optimize the design for structural, thermal and dynamic requirements.

The steps involved in carrying out analysis using Pro/MECHANICA are given below:-

- ✓ 3D part modeling

  Make three dimensional model of an automotive vacuum suspended power brake using Part and Assembly mode of Pro/ENGINEER Wildfire 3.0.

- ✓ Define the FEA model

  At least there are three basic elements to be specified to define a FEA model, i.e., material, loads and constraints.

- ✓ Define material properties, loads and constraints

  Material assign to the master cylinder in the analysis was LM12The material Properties are given in section 4.1. The inner uniform pressure in the master cylinder piston was taken as 4.66 N/mm^2.

- ✓ Grid Generation

  Mesh generation is called pre-processing for finite element method. Pro/MECHANICA automatically generates finite element mesh. In advanced application of Pro/MECHANICA, one can specify important regions on the model, in which more detailed mash can be generated.

- ✓ Run a static analysis

  After analysis was defined completely, it was required to run the analysis.

- ✓ Review the results

  Once the analysis had run successfully, it was important to review the results. After reviewing the results, it was found that the stresses were within the permissible/safe limit.

The results of the stress analysis of the existing Vacuum suspended power brake are shown in figures.

Figure.9 master cylinder.

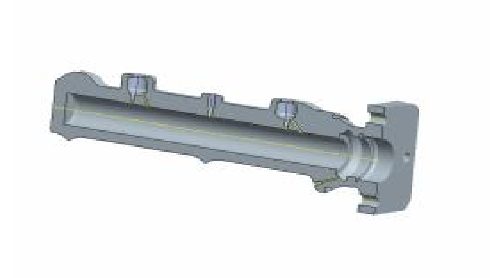

Figure10 cut section of master cylinder.

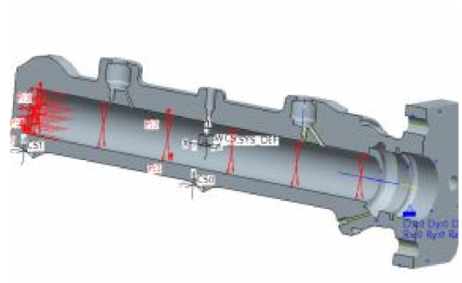

Fig.11 Uniform internal pressure on master cylinder.

Fig.12 Grid generation on master cylinder.

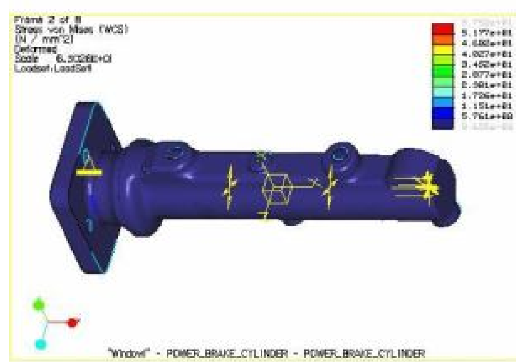

Figure13 Von mises stress on master cylinder.

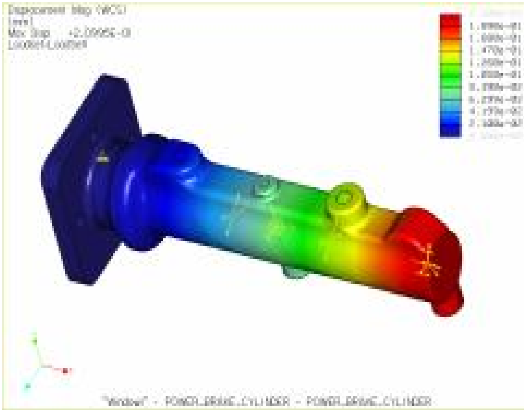

Figure14 Deformation of master cylinder.

VI. RESULTS AND CONCLUSION

The stress analysis of a master cylinder was carried out and it was observed that the stresses induced were found to be well within the allowable /safe limit.

As per design the working tensile strength of master cylinder is 40.48 N/mm^2. As per Pro/MECHANICA analysis the working stress of master cylinder is 57.52 N/mm^2 which is within limit so design is safe**.**

VII. REFERENCES

[1] Heinz-Heisler "advance vehicle technology", second Edition, 2002, ISBN 07506 51318, Elsevier Butterworth-Heinemann pp. 494-496,

[2] R.K.Rajput(2007), "A textbook of Automobile Engineering", First Edition, Laxmi Publication (P) Ltd., New Delhi – 110002.

[3] Julian happian- smith "An introduction to modern vehicle design", First Edition, 2002, P.C. Brooks and D.C. Barton, ISBN 07506 50443, Elsevier Butterworth-Heinemann pp .157

[4] Tickoo Sham, Maini Deepak, "Pro/ENGINEER Wildfire 4.0 for Designers", 2009, ISBN 1-932709-19-, CADCIM Technologies, USA.

[5] S.Kelley David.,"Pro/ENGINEER Wildfire Instructor", First Edition, 2005, ISBN 0-07-286520-2, McGraw-Hill Higher Education.

[6] "Getting *Started* with Pro/ENGINEER® Wildfire™", April 2003, Parametric Technology Corporation (PTC).

[7] R.Chandrupatla Tirupathi and Belegundu Ashok D., "Introduction to Finite Element in Engineering", Third Edition, 2002, Prentice-Hall India Ltd.