Stress Calculation in Two Wheeler Disc Brake Master Cylinder Aluminium Piston in CAE

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Abstract— Now a days most of the two wheeler vehicles have disc brakes to their front wheel. This disc brake consists of master cylinder which is housing for a plunger which acts as a piston to create and push the pressurized oil into the oil hose of the front disc brake system. This piston is made of aluminum which is heavy in weight as compare to plastic. In this project we are focusing on to change the material of the piston from aluminum to plastic.

To achieve this, first part of the project, through CAE, stresses in Aluminum are found out. Possibility for Design optimization and Design for manufacturability will also be checked.

The advantages of the changed material piston are the low cost and superior material properties. We will study other advantages of using plastic material in piston.

With above proposal we will get reduction in piston weight, design cost and productivity improvement due to material change of the piston from metal to plastic.

Index Terms— master cylinder piston, material change, plastic material, design and optimization.

I. INTRODUCTION

The disc brake consists of master cylinder which is housing for a plunger which acts as a piston to create and push the pressurized oil into the oil hose of the front disc brake system. This piston is made of aluminum which is heavy in weight as compare to plastic. There is a possibility of scarcity of aluminium material makes it costly and hence it is necessity to find the more easily and abundant available material. In this project we are focusing on to change the material of the piston from aluminum to plastic. To achieve this, we first calculate the stress occurred in piston through CAE.

II. PROBLEM STATEMENT

This master cylinder piston is made up of aluminium which is heavy in weight as compare to plastic. The pistons which are used in hydraulic wheel cylinders and hydraulic master cylinders of the common hydraulic brake systems are made of aluminium and forming process consists of die casting the metal to give it the desired shape and then grinding the outer surface of the piston to obtain a piston diameter which will conform closely to the inner diameter of the cylinder in which the piston is to be used [7]. While metals such as aluminium are satisfactory, proper combinations of non-metallic materials including some ceramics and filled hard plastic such as high glass content nylon are useful in some instances [5]. The advantages of the changed material piston are the low cost and superior material properties. The conventional aluminium piston of the master cylinder is manufactured by the process of casting or machining. In the second part, we are manufacturing the piston by using plastic material through injection molding process and machining route.

III. LITERATURE REVIEW

Schuller w., eckstein u., [2] invented and manufactured a piston by using plastic material such as polytetrafluorethylene. The one end of the piston is called strike surface on which cam element exerts the linear forces. The wear resistant material such as metal like hardened steel or sintered ceramic is used as cam strike piece. This material is used as cam strike piece in disk shaped in between piston and strike surface to bear the stresses due to friction. The disk shaped cam strike piece is used as insert in the injection molding tool and plastic is injected around the insert except on the strike face. The piston is manufactured in one operation by using injection molding procedure which is simple, quick and cheap method. As the piston is manufactured by using plastic, it has the advantage of positive sliding property while sliding linearly in cylinder housing.

Hauser m., alaze n., et al. [3] to manufacture a master cylinder piston easily and at low price rate, inventors proposes a methodology that the piston includes a sleeve shaped part and a valve seat part made of plastic material and the valve seat part is press fitted into shaped part. This methodology allows a small and compact design of master cylinder. The other advantages of the methodology that it has minimum components that are manufactured from simple and low rate components. They optimized the piston for its manufacturability while maintaining its functionality.

Nakamura k., [4] manufactured a piston and master cylinder body from fiber glass nylon material as strengthened resinous material by molding operation which produces as single component as a result reduces weight and cost. The other objective of the invention is to produce a new and improved piston for a master cylinder which eliminates the previous disadvantages of piston. They found that, as the plug rests on the center of the concave surface of the piston, while manufacturing the piston by molding process, the flow of resinous material will improve and hence the dimensional accuracy of piston will be improved.

Schard m. M., [5] manufactured the master cylinder piston as a composite assembly. This piston has an insert made of metallic, ceramic or high glass filled nylon plastic. The glass filled nylon plastic is molded around this insert to form a complete finished piston. The material of insert should be rigid enough and strong to transmit the longitudinal forces to which the piston is experienced without change in shape and wear through its lifetime.

Genz o. F., park e., [6] have following claims,

1) The piston assembly having two body members which have diameter less than the inside diameter of the cylinder. The body members formed a piston which reciprocates inside the cylinder. This movement of piston assembly increases the temperature of oil and piston assembly as well. To compensate the expansion of piston assembly, the materials used for piston body assembly have higher degree of thermal expansion than the cylinder material.

2) These body members have axial grooves on their surface to compensate a “O” ring.

3) Overall, the piston assembly comprises of the packing rings on piston assembly body, compression washer and a threaded nut on piston rod for varying the body members diameter and also the axial grooves on the surface. These body members are so formed that they can expand if temperature of oil or piston assembly increases.

III. FORCE REQUIRE TO STOP VEHICLE

From the reference [1] for calculating the force required stopping the vehicle, we have considered 150cc two wheeler of mass 144kg is travelling at 60kmph. Determine 1) kinematic energy it possess. 2) The average baking force to bring it to rest in 30 meters.

where, KE = kinetic energy of vehicle
M = mass of vehicle, kg
U = speed of vehicle, m/s

The work done in bringing the vehicle to rest is given by

$$W_D = FS, \qquad (1)$$

where, W_D = work done, J

F = average braking force, N

S = distance travelled, m

1) Speed of vehicle U = 60 x 1000/ 60 x 60 = 16.67 m/ sec.

2) Kinematic energy = ½ MU² (2)

= ½ x 144 x (16.67)²

∴ Kinematic energy = 20008 N

3) while braking a moving vehicle to a standstill, the work done by the brake drums must equal the initial kinetic energy possessed by the vehicle so that Work done to stop vehicle = change in vehicle kinetic energy

∴ KE = W_D (3)
∴ FS = ½ MU² (4)
∴ 30F = 20008
∴ F = 20008/30
∴ F = 666.933N

We can round off the figure to its nearest value and consider it as 670 N. We can use this value of force for applying the stress in CAE.

IV. CAD MODEL AND STRESS CALCULATION

The locally manufactured existing aluminium piston is used for this work. To avoid human errors in measurement of this piston, this piston is scanned on machine and the raw cad model data is saved in .stl file format.

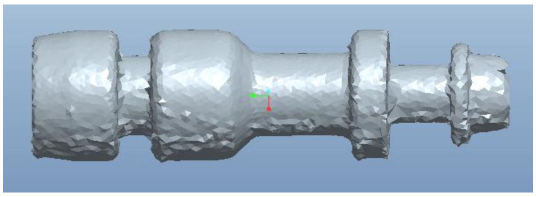

Fig. 1 Scanned model of piston

This file is imported in Creo CAD software to remove rough edges or repair broken model. After working on this raw cad model, the improved and repaired cad model is look like as follows,

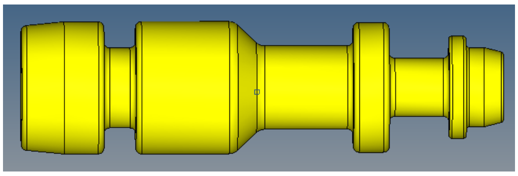

Fig. 2 Repaired cad model of piston

This repaired CAD model is saved in .igs file format and is imported to Hypermesh software for meshing.

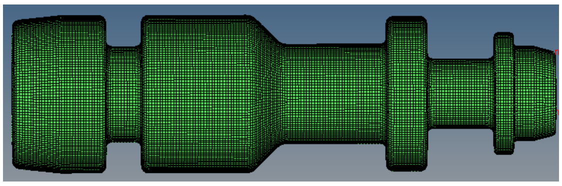

Fig. 3 Meshing of piston

This model is meshed by keeping element size as 0.2mm and analyzed in Abaqus for Non Linear analysis. The loading of 670 N is applied on the spring face and the lever face is constrained for all DOF.

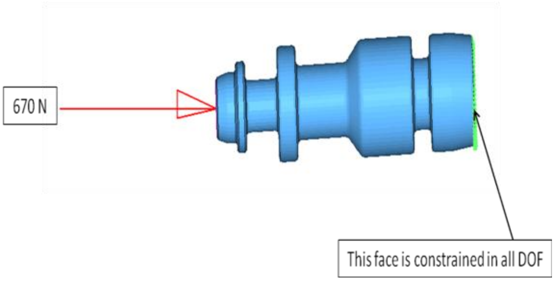

Fig. 4 Load application on piston

As this piston is made of Aliminium, for analysis purpose we consider the material properties of Aluminium Alloy 6026 grade available in drawn rod shape.

Table 1. ALUMINIUM 6026 PROPERTIES

Sr. No	Material	Density	Tensile Modulus	Poisson's Ratio	Tensile Stress at Break	Strain at Break
		(tonnes/ mm³)	(MPa)		(MPa)	(%)
1	Aluminum 6026	2.72E-09	69000	0.33	360	4

The analysis gives the following results for Force vs Displacements in X, Y, Z axis,

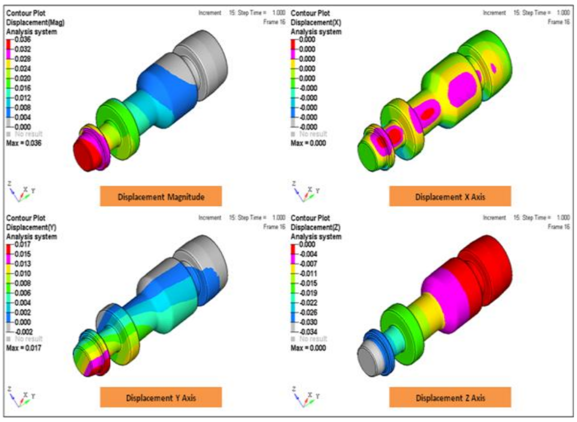

Fig. 5 Force vs Displacement in X, Y, Z axis

For piston, the stress-strain plot is as shown below,

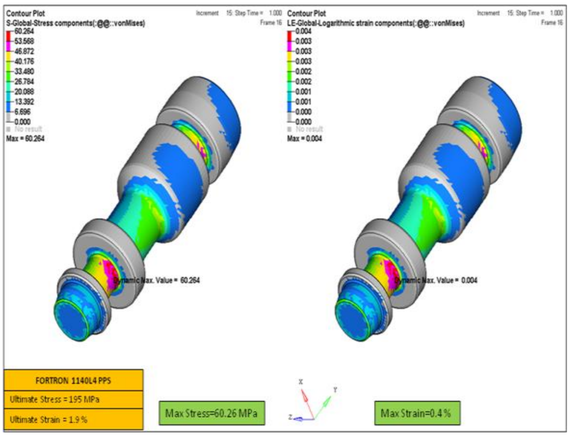

Fig. 6 Stress-Strain Plot

From above figures 5 and 6, we can get the analysis results expressed in tabular form as follows,

Table 2. TABULAR REPRESENTATION OF ANALYSIS RESULTS FOR ALUMINIUM

Description	Unit	Value
Force Applied	N	670
Overall Displacements	mm	0.036
Displacements in X axis	mm	0
Displacements in Y axis	mm	0.017
Displacements in Z axis	mm	0
Ultimate Stress	MPa	360
Maximum Stress observed	MPa	58.666
Ultimate Strain	%	4
Maximum Strain observed	%	0.1

From above Table 2, we get to know that the observed results of stress and strain are well below the allowed stress and strain. The overall displacement occurred in piston is 0.036mm and displacement in X, Y and Z axis is negligible. These results depicts that the existing design of aluminium piston is well designed and withstand the forces. We can use the same design to replace the aluminium material with plastic. We are going to use same model for analysis of piston using plastic material. The plastic material is selected considering the main criteria's such as,

1) It should be high temperature resistance

2) It should be wear resistance

3) It should be chemically inert

4) hence it should maintain mechanical properties

5) have low cost and relevant characteristics.

The plastic materials such as Nylon, PPS and other plastic materials are to be checked for its functionality and design for manufacturability.

V. RESULTS

1 Weak Region on Piston

From the analysis figures, it is seen that, the slot diameter at “O” rings place at two locations are weak for stress and strain. But this stress and strain are within the allowable limit i.e. ultimate stress and strain, this does not show the breaking of plastic piston.

2 Causes of Stress Intensity

Although the stress and strain are occurred at two locations of slot diameter, are very minor and piston can survive to this.

VI. REMARKS

With above procedure, we can achieve reduction in piston weight, design cost and productivity improvement due to material change of the piston from metal to plastic.

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