Design & Development of Hydraulic Disc Brakes for Solar Operated Vehicle

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Abstract- *Humans have always been fascinated by the idea of going faster than before. However as the speeds of vehicles go up the technology required to safely stop these vehicles must evolve. Braking systems have had tremendous transformations from lever type drum brakes to multi layered carbon ceramic disc type Hydraulic brakes. The Present research work aims at studying the analysis and development of hydraulic brake system. This research incorporates Brake Performance and the calculation for given vehicle category.*

Keywords- Brake pedal force, Stopping distance, Pedal ratio, Heat generation, Rolling radius, Brake efficiency.

I. INTRODUCTION

The hydraulic brake is an arrangement of braking mechanism which uses brake fluid, typically containing ethylene glycol, to transfer pressure from the controlling mechanism to the braking Mechanism. Hydraulic brakes work on the principle of Pascal's law which states that "pressure at a point in a fluid is equal in all directions in space". According to this law when pressure is applied on a fluid it travels equally in all directions so that uniform braking action is applied on all four wheels.

In a hydraulic brake system (HBS), when the brake pedal is pressed, a pushrod exerts force on the piston(s) in the master cylinder, causing fluid from the brake fluid reservoir to flow into a pressure chamber through a compensating port. This results in an increase in the pressure of the entire hydraulic system, forcing fluid through the hydraulic lines toward one or more calipers where it acts upon one or two caliper pistons sealed by one or more seated O-rings. The brake caliper pistons then apply force to the brake pads, pushing them against the spinning rotor, and the friction between the pads and the rotor causes a braking [1].

II. TECHNICAL CONTENT

2.1 Disc brakes:

- The disc brake was invented by "FREDRICK WILLIAM LANCHESTER" a Birmingham car maker, designed first disc brakes in 1902 & in 1949 production of first disc brake was incorporated & acknowledged by automobile industries.
- The disc brakes consist of disc brake rotor which is attached to wheel & caliper, which holds the pads.
- Hydraulic pressure from the master cylinder causes the caliper piston to clamp the disc brake rotor between the disc brakes pads.
- This creates friction between the pads & rotor, causing your car to retard or stop.

Types of disc brakes

I. Fixed caliper
II. Floating caliper

2.1.1 Floating Caliper:

- A caliper bracket is solidly mounted and the caliper itself within that bracket isn't solidly mounted so it can slide left and right via pins and bushings on the bracket.
- A piston on the inner side of the disc pushes that brake pad as if to move the disc but because the disc can't slide, the force pulls the sliding caliper with another brake pad unto the other side of the disc.
- As per our requirement we are using the caliper of Activa, which has piston diameter of 30mm.
- The advantages of the floating caliper is that it is cheaper and lighter than the fixed caliper as it uses less parts and is more compact.

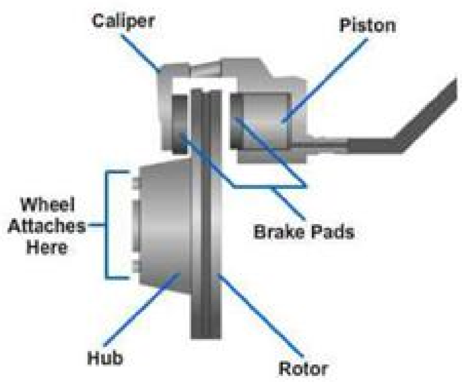
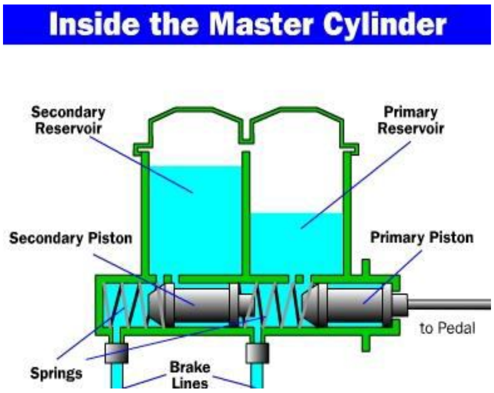


Fig: Disc brakes

2.1.2 Master Cylinder:

- When we press the brake pedal, it pushes on primary piston through a linkage.



- Pressure is built in the cylinder and the lines as the brake pedal is depressed further.
- The pressure between the primary and secondary piston forces the secondary piston to compress the fluid in its circuit.
- If the brakes are operating properly, the pressure will be same in both the circuits.
- If there is a leak in one of the circuits, that circuit will not be able to maintain pressure.
- In our vehicle we are using the master cylinder of Maruti 800, which have 4 ports & the diameter of piston is 19.5mm [3].

2.1.3 Disc:

- Drilled brake discs are suitable for a wide range of applications, operating temperatures and driving environments (especially wet weather).
- The heat generated due to friction escape from this hole.
- The disc that we are using is of Activa, having outer diameter of 190mm & material of disc is Cast Iron [2].

(C.I).

Fig: Disc

2.1.4 Brake Fluid:

There are two types of fluids

- Petroleum and Non petroleum

99.9% of vehicle runs on non petroleum based brake oil
It is further classified into

- Silicon base (DOT5)
- Glycol base (DOT3,DOT4,DOT5.1)

Here we are using DOT3 for our vehicle as it has more advantages than other type. Its Dry Boiling Point Temperature is 205 degree Celsius & Wet Boiling Point Temperature is 140 degree Celsius.

It absorbs 1 to 2 % of water per year depending on the climate.

III. DESIGN APPROACH

The two main types of braking systems under consideration were Drum and Disc brakes. But in case of drum braking there is a high possibility of mud and debris to gather in the space between the shoe and the drum. Same problem is faced in mechanical disc brakes, but not in hydraulic disc brakes. Hydraulic brakes are found to be suitable for all type of terrain across worldwide. So we have decided to use hydraulic disc brakes in the front and the rear. The internal diameter of our rim is 12 inches, so we need a suitable disc and caliper assembly.

- We will be using discs and double piston calipers of Activa 125 which are convenient.
- We are using TMC of Maruti 800.
- We are using DOT 3 (department of transportation 3) brake fluid for our vehicle as it perfectly suits our

braking specifications ; it has dry boiling point of 205°C and wet boiling point of 140°C which is enough and suitable to stop our vehicle running at 11.11m/sec efficiently.

3.1 Calculations:

Theoretical calculations:

Assumptions:

Velocity=V=40km/hr = 11.11 m/s, Weight=W=300kg

Fd = the force applied to the pedal pad by the driver
= 440N

L1/L2 = Pedal ratio = 4:1

Co-efficient of Friction between caliper & disc = μ
= 0.37

Co-efficient of Friction between tyre & road for dry = μ1
= 0.84

Co-efficient of friction between tyre & road for wet = u2
= 0.4

1. Brake pedal force = Fbp = Fd × {L1/L2}
Fbp = 1760 N
2. Stopping Distance = S = $V^2/2\mu g$
= 7.48 m
3. Deceleration = a = $V^2/2s$
= 8.24 m/s2
4. Stopping time = t = V/a
= 1.34 secs
5. Total force required to stop the vehicle = F = m × a
= 2472 N

Practical calculations:

1. Brake pedal force = Fbp = Fd × {L1/L2}×0.9
Here, considering 10% losses & 90% efficiency of braking force
Fbp = 1584 N
2. Stopping Distance = S = Braking distance + Reaction Dist.
Braking distance = V^2 / 250×μ
Reaction distance = V × reaction time (1 secs)
S1 = 11.69 m ……..FOR DRY
S2 =12.344m ……..FOR WET

3. Deceleration = a = $V^2/2s$
a_1 = 5.27 m/s2 …….FOR DRY
a_2 = 4.999m/S2 …....FOR WET
4. Stopping time = t = V/a
t_1 = 2.10 secs
t_2 = 2.334 secs

5. Pressure in the master cylinder = $P_{mc} = F_{bp} / A_{mc}$
where, Am/c = the effective area of the master cylinder hydraulic piston
= 0.000298 m2
P_{mc} = 5.303*106 N/m2

6. Pressure in brake pipes or hoses : Assuming no losses along the length of the brake lines, the pressure transmitted to the calipers will be equal to:
$P_{cal} = P_{mc}$`
Where, P_{cal} = the hydraulic pressure transmitted to the caliper
= 5.303*106 N/m^2

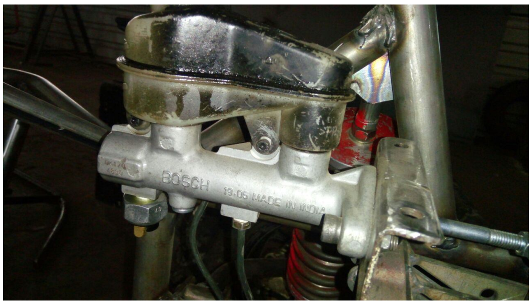
7. Clamping force = F_{clamp} = 2 × Pcal × Acal (for both sides)
Where, A_{cal} = 0.000706 m^2
Fclamp1 = 5629.972 N
Fclamp2 = 8444.958 N
8. Caliper force = Fcal = 5629.972/2
Fcal1= 2814.986 N
Fcal2 = 4222.479 N
9. Frictional force = $F_{fri} = F_{clamp} \times \mu(0.37)$
F_{fri1} = 2083.089 N
F_{fri} = 3124.634 N
10. Front dyanmic rolling radius = R = 0.97 × r
R = 0.145m
Here, r = radius of inner wheel rim
(as we are using tyre of size R12) r = 0.15, Considering 97% of tyre is used and lower portion of tyre is pressed due to weight.

11. Braking torque = Tb = F_{fri} × R
= 402.279 N-m
12. Kinetic energy = K.E = 0.5 × m × V^2
= 18514 Joules
13. Heat dissipated by rotors = Q_g
As the heat dissipated by the rotors is equal to the kinetic energy of wheels
Q_g = K.E = 18514 Joules (for 3 rotors)
Q_g = 6171.33 Joules (for 1 rotor)
14. Efficiency of brake = F_{bp} / weight
= 53.702%
15. Torque (front/rear) = P×A× R_{eff} ×u
$T_{(FRONT)}$ = 1366.46 N-m
$T_{(REAR)}$ = 505.243 N-m
16. Bias%(front/rear) ;
Bias% $_{(front)}$ = TF/TF+TR × 100
=73.006%
Bias% $_{(REAR)}$ = TR/TR+TF × 100
= 26.993%
17. Bias Index = $T_{(front)} / T_{(rear)}$
= 2.704

IV.CONCLUSION

Hence from above Calculations it can be concluded that, for locking the wheels moving with a velocity of 40km/hr, total clamping force of 5629.972 N is required for front wheels and 8444.958 N for the rear wheels so that the vehicle get stopped in just 2.10. seconds at stopping distance of 11.69 meters.

Thus Hydraulic Braking System is convenient for our Solar Operated Vehicle.



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