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An Approach to Optimize the Disc Brake of A Motor Cycle

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Abstract: ***Automobile braking system is one of the most important mechanical devices. The disc brake system is a device for slowing or stopping the rotation of a wheel. Here we are doing a analysis disk brake of Bajaj Pulsar 150cc.The cost of disc rotor of pulsar is around 900 Rs. And that of friction pad is around 150 Rs. So by keeping the braking torque constant if we reduce the diameter of disc rotor and increase the friction pad area then we can reduce the cost and weight of disc assembly up to some extent.***

I. INTRODUCTION

A disc brake is a wheel brake which slows rotation of the wheel by the friction caused by pushing brake pads against a brake disc with a set of calipers.

To stop the vehicle, friction material in the form of brake pads is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc brake and attached wheel to slow or stop.

Compared to drum brakes, disc brakes offer better stopping performance, because the disc is more readily cooled and disc brakes recover more quickly from immersion. (wet brakes are less effective).

II.COMPONENT OF DISC BRAKE

A. Disc rotor

The brake disc is the disc component of a disc brake against which the brake pads are applied.

Generally the disc rotor is made of gray cast iron and is either solid or ventilated. The ventilated type rotor consists of a wider with cooling fins cast through the middle to ensure good cooling. Some ventilated rotors have spiral fins which creates more air flow and better cooling.

- Material of disc rotor.
  - ✓ Nickel Chrome Steel
  - ✓ Aluminum Alloy
  - ✓ Cast Iron
  - ✓ Carbon Reinforced polymer

Many higher-performance brakes have holes drilled through them for heat dissipation purposes. This is known as cross-drilling.

Discs may also be slotted, where shallow channels are machined into the disc to aid in removing dust and gas. Slotting is the

preferred method in most racing environments to remove gas and water and to deglaze brake pads.

Motor cycle disc rotors are made from the Nickel Chrome steel

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Fig. 1 Disc rotor

Nickel Chrome Steel		
Sr. no	Name	Property
1	Density	7830 Kg/M2
2	Fatigue strength	600 MN/M2
3	Elastic limit	
	Tension	420 MN/M2
	Compression	420 MN/M2
	Shear	250 MN/M2
4	Modules of elasticity(E)	210 GN/M2
5	Endurance limit bending	350 MN/M2
6	Elongation in 50 mm	17-26%
7	Brinell Hardness	117-325

Table 1.Property of Nickel Chrome steel

B. Brake Pad

Different brake design application requires different kind of friction material. The coefficient of friction must remain constant over a wide range of temperature, the brake pad must not wear out rapidly nor should they wear the disc rotors, should withstand highest temperature without fading it should be able to do all this without any noise. Material which make up the brake pad include Friction modifiers such as graphite and cashew nut shells, alter the friction coefficient. Powdered metal such as lead, zinc, brass, aluminum and other metals increase a material's resistance to heat fade. Binders are the glues that hold the friction material together. Phenolic resin is the most common binder in current use. Fillers are added to friction material in small quantities to accomplish specific purpose such as rubber chips to reduce brake noise.

Brake Pad Materials

- ✓ Asbestos
- ✓ Semi-Metallic
- ✓ Non-Asbestos Organics
- ✓ Low Steel
- ✓ Carbon

Fig 2. Brake pad

Asbestos brakes were used for years because of their extremely high friction coefficient, but advances in science has shown that it is a cancer causing substance. Now a days non asbestos semi metallic material is widely used due to following properties.

- Properties of Semi-Metallic Pads
- ✓ Low to medium coefficient of friction ~ 0.28 –0.38
- ✓ Excellent wear resistance.
- ✓ Less change in co efficient of friction with respect to temperature.
- ✓ Create a less Noise, Vibration & Harshness compared to NAOs
- ✓ Contains no copper
- ✓ Low initial cost
- ✓ High durability

C.Calipers

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The brake caliper is the assembly which houses the brake pads and pistons.

Calipers are of two types, floating or fixed. A fixed caliper does not move relative to the disc and is thus less tolerant of disc imperfections.

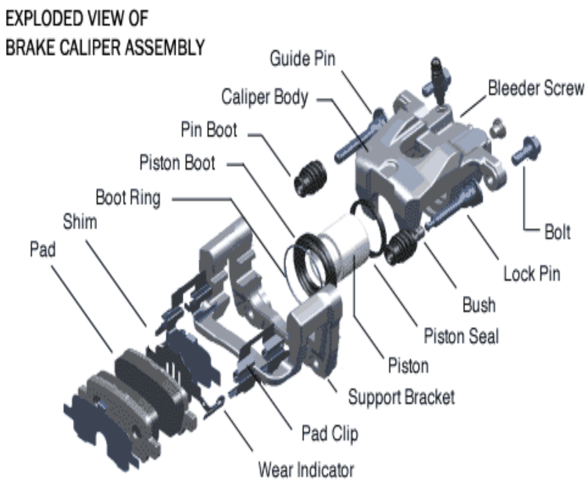

Fig 3. Exploded view of caliper assembly

It uses one or more single or pairs of opposing pistons to clamp from each side of the disc, and is more complex and expensive than a floating caliper.

A floating caliper (also called a "sliding caliper") moves with respect to the disc, along a line parallel to the axis of rotation of the disc; a piston on one side of the disc pushes the inner brake pad until it makes contact with the braking surface, then pulls the caliper body with the outer brake pad so pressure is applied to both sides of the disc.

D. Pistons and cylinders

The most common caliper design uses a single hydraulically actuated piston within a cylinder, although high performance brakes use as many as twelve. Modern cars use different hydraulic circuits to actuate the brakes on each set of wheels as a safety measure. The hydraulic design also helps multiply braking force. The number of pistons in a caliper is often referred to as the number of 'pots', so if a vehicle has 'six pot' calipers it means that each caliper houses six pistons.

III. DESIGN AND CALCULATION

Force and Torque Equations

$$F = \int_{\theta_1}^{\theta_2}\int_{r_i}^{r_o} pr\,dr\,d\theta = (\theta_2 - \theta_1)\int_{r_i}^{r_o} pr\,dr \qquad \textit{Equation 1}$$

$$T = \int_{\theta_1}^{\theta_2}\int_{r_i}^{r_o} fpr^2\,dr\,d\theta = (\theta_2 \quad \theta_1) f \int_{r_i}^{r_o} pr^2\,dr \qquad \textit{Equation 2}$$

Where

- ✓ p = fluid pressure
- ✓ r1, r0 = inner, outer radius of disc
- ✓ θ1, θ2= initial, final contact angle
- ✓ f = friction coefficient
- ✓ F=Force on pads
- ✓ T=Torque generated by pads

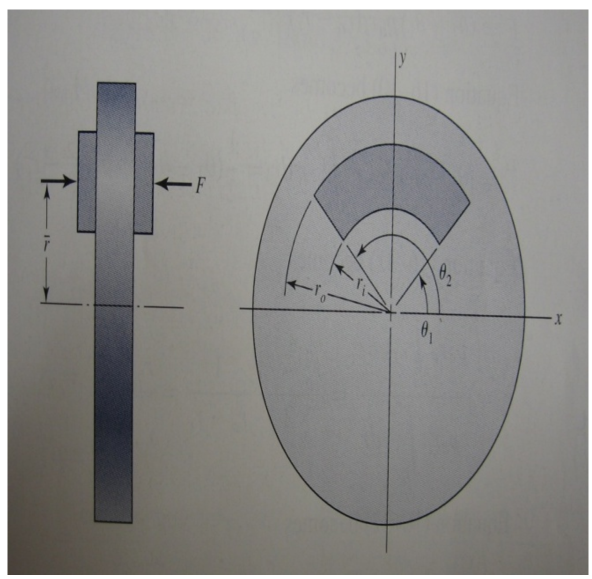

Fig 4 Geometry of Contact Area

Calculation

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Mass of Vehicle = 150 kg
Mass of vehicle with rider = 150+120= 270 kg.
Distance travel by vehicle after applying brake (S)= 45 m.

Speed of vehicle = V1 (60 km/h= 16.68m/s) and V2(0 km/h).
Diameter of caliper piston= 25mm =0.025 m.
Area of Caliber Piston = 4.90x10^-4 m2.
Wheel radius of Vehicle = 0.35 m
Effective radius of brake pad (r) = 0.112m
Co-efficient of friction = 0.4

Retardation:

$$f = \frac{V^2}{2S} = \frac{16.68^2}{2 \times 45} = 3.08 \frac{m}{s^2}$$

Breaking Force:

$$F_b = M_w \times f = 150 \times 3.08 = 465N$$

Breaking Torque:

$$T_b = F_b \times W_r = 465 \times 0.35 = 165NM$$

Now Take Data of Existing disc rotor And find the required brake fluid pressure with the help of equation 1

$$\theta_1 = 70, \theta_2 = 115, r_0 = 0.120m, r_i = 0.095m$$

$$F_b = \frac{1}{2}(\theta_2 - \theta_1) \times P_b \times (r_o^2 - r_i^2)$$

$$465 = \frac{1}{2}(115 - 70)\frac{\pi}{180} \times P_b \times (0.120^2 - 0.095^2)$$

$$P_b = 22.030 \times 10^4 \frac{N}{M^2}$$

Now find the same braking Force by increasing the pad area and decreasing the radius of disc
Here we increase the pad area from 45 degree to 90degree and according to that we will find the radius of disc.

$$\theta_1 = 45, \theta_2 = 135, r_0 = ?, r_i = r_o - 0.025$$

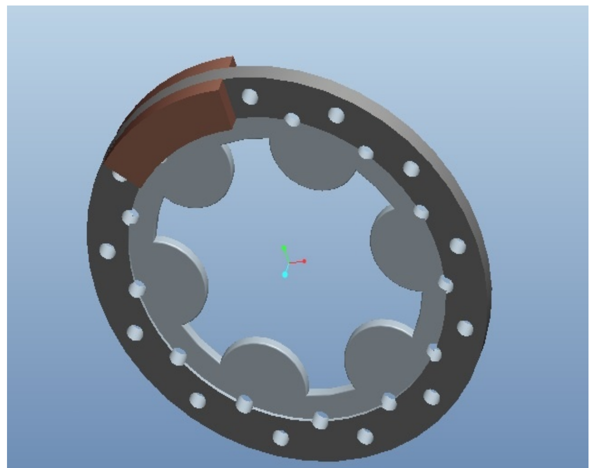
$$F_b = \frac{1}{2}(\theta_2 - \theta_1) \times P_b \times (r_o^2 - r_i^2)$$

$$465 = \frac{1}{2}(135 - 45)\frac{\pi}{180} \times 22.030 \times 10^4 \times (r_o^2 - r_i^2)$$

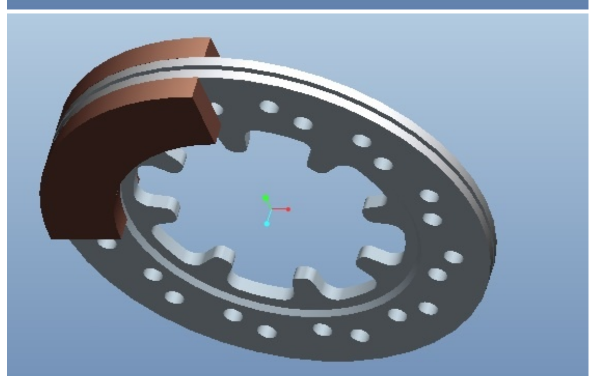
$$r_o = 66.25mm \approx 70mm$$

By solving this equation we will get

$$r_o = 70mm \approx 90mm, r_i = 90 - 30 = 60mm$$



Existing disc rotor and friction pad assembly



New Disc Rotor and Friction pad assembly

IV .RESULT ANALYSIS

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So we can reduce the radius of disc ro (120mm to 90mm) and ri (95mm to 60mm)

Here the mass density of disc material which is nickel chrome steel is 7800 kg/m3

So weight of disc before is 0.4410 kg and after is 0.248=0.250 kg.

So reduction in weight is almost 44%.

Cost of disc is depend on so many factors and among this factors some factors like transportation cost, material handling cost, different kinds of taxes etc. are directly depend on material.

So if we reduce the diameter of disc then we can reduce the material consumption and ultimately we can reduce the cost of disc.

Cost of disc is around 900Rs. So if we reduce the material consumption than we can reduce the cost up to 510 Rs.

And same way cost of disc pad is around 150 Rs. So if we increase the pad material area up to 41% than cost will increase up to 250 Rs.

	OLD	NEW
WEIGHT (Rotor)	0.4410 kg	0.250 kg
COST(Disk assembly)	1050 Rs	770 Rs
Total reduction in weight	44%	
Total reduction in Cost	28%	

Table 2 . Comparison of old and new disk

So by performing this experiment we can reduce the cost of disc approximately up to 390rs. An increase in cost of pad is 100 rs.

So by performing this experiment we can reduce the approximate cost of disc brake up to 28% and weight up to 44% and it will also increase the efficiency of bike up to some extent.

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