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Design & Implementation of Disc Brake Rotor By using Modified Shapes

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ABSTRACT:

This work is presented with "Design of disc brake with modified shapes" which studies about on disc brake rotor by modeling & analysis of different shapes of slots of different vehicle's disc brake rotor with same outer diameter & inner mounting position of holes on wheel hub as like Bajaj Pulsar 150.Analysis done on real model of disc brake rotor of Bajaj pulsar 150 and disc brake rotor of different shapes of slots of different vehicle's disc brake rotor. Therefore, it gives optimize stress, deformation & weight of the modified disc brake rotor & also good heat dissipation. On the basis of weight parameter implementation of new disc brake rotor is done. Hopefully this project will help everyone to understand experimental verification of disc brake rotor and how implemented disc brake works more efficiently, which can help to reduce the accident that may happen in each day

Keywords- *Disc brake, optimize, slots, heat dissipation, experimental verification.*

1. Introduction

In this project we study about disc brake rotor analysis of different shapes of slot. Static structural and steady state thermal analysis is done on real model of disc brake rotor of Bajaj Pulsar 150ccDTSi and also on different shapes of disc brake rotor with keeping same outer diameter and inner mounting position of hole on wheel hub. Different shapes of slots are to modify the von mises stresses, deformation & weight of disc rotor as well as good heat dissipations across the disc brake rotor. Therefore, we can optimize number of shapes to estimate the optimum von mises stresses, deformation & weight the in disc brake rotor.

The knowledge gained from this project is to be able to understand the steps needed in structural &thermal analysis of disc brake rotor by using FEA method. The methods used in this project can later be used in future as reference for similar research and development .The disc brake rotor could be studied on the various areas such as material improvement on the disc brake rotor, vibration on the disc brake, noise and squeal of the disc brake and thermal stress analysis on the disc brake rotor. Hopefully this project will help everyone to understand structural and thermal analysis of disc brake rotor of modified shapes and how disc brake works more efficiently, which can help to reduce the accident that may happen in day to day life.

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2.MATHEMATICAL MODELING

2.1 Tangential force

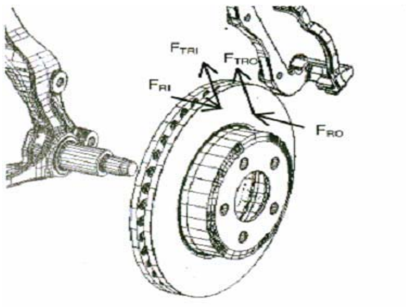

Fig. 2.1 Forces acting on rotor due to contact with brake pads.

The forces acting on the inner and outer rotor faces due to contact with brake pads are shown in Fig. 5.1

Hence the expressions for tangential force were:

2.1.1 Tangential force between pad and rotor (inner face)

$$F_{TRI} = \mu_1 * F_{RI} \quad (1)$$

2.1.2 Tangential force between pad and rotor (outer face)

$$F_{TRO} = \mu_0 * F_{RO} \quad (2)$$

2.2 Brake Torque

2.2.1 Brake torque in case of pad and rotor difference materials

The expression for brake torque was developed as a function of the two tangential forces and the effective radius of the pad/rotor interface.

$$\mathrm{T_B} = \left(\mu_1 * \mathrm{F_{RI}} + \mu_0 * \mathrm{F_{Ro}}\right).\mathrm{Reff} \quad (3)$$

2.2.2 Brake torque in case of pad and rotor same material

With the assumption of equal coefficients of friction and normal forces FR on the inner and outer faces:

$$T_B = 2 * \mu * F_T * R \quad (4)$$

2.3 Distance travelled (in meter) by the vehicle before it come to rest

Let x = Distance travelled (in meter) by the vehicle before it comes to rest.

Tangential braking force acting at the point of contact of the brake and work done = F_T. x;

When,

$$\mathrm{F_T} = \mathrm{F_{TRI}} + \mathrm{F_{TRO}} \quad (5)$$

$$\text{Kinetic energy of the vehicle } = \frac{\mathrm{mv^2}}{2} \quad (6)$$

In order to bring the vehicle to rest, the work done against friction must be equal to kinetic energy of the vehicle. Therefore equating Equation 10 and Equation 6,

$$F_T.x = \frac{mv^2}{2} \quad (7)$$

Let N = Required number of revolution.

Distance travelled by the vehicle (x),

$$x = \pi DN(8)$$

Where D = Diameter of rotor disc brake standard

2.4 Calculation

In This Project Study Standard of Vehicle name “Bajaj Pulsur 150”

Table No. 2.1Standard specification of Bajaj Pulsar 150. [1]

Sr. No.	Factors	Parameters
1	Rotor Disc Dimension	240 mm. (240×10^{-3} m)
2	Rotor Disc Material	Gray Cast Iron
3	Pad Brake Area	2000 mm^2 (2000×10^{-6} m^2)
4	Pad Brake Material	Asbestos
5	Coefficient of Friction (Wet)	0.08-0.12
6	Coefficient of Friction (Dry)	0.2-0.5
7	Permissible Temperature	250 ºC
8	Maximum Pressure	1 MPa (10^6 Pa)

2.5 Tangential force

2.5.1 Tangential Force between Pad and Rotor. (Inner Face), F_{TRI}

$$F_{TRI} = \mu_1 * F_{RI}$$

Where F_{TRI} = Normal force between pad brake and rotor (inner)

$\mu_1 = 0.5$

$$F_{RI} = \frac{\text{Pmax}}{2} \times \text{PadBrakeArea}$$

So,

$$F_{TRI} = \mu_1 * F_{RI}$$

$$F_{TRI} = 0.5 * \frac{(1 \times 10^{6})}{2} * (2000 \times 10^{-6})$$

$$F_{TRI} = 500 \text{ N}$$

2.5.2 Tangential Force between Pad and Rotor (Outer Face), F_{TRO}

In this $\mathbf{F_{TRO}}$equal $\mathbf{F_{TRI}}$because same normal force and same material.

2.6 Brake torque (T_B)

With the assumption of equal coefficients of friction and normal forces F_R on the inner and outer faces:

$$T_B = F_T * R \qquad (9)$$

F_T = 1000 N.

R = Radius of rotor disc.

So, $T_B = 1000 * 120 * 10^{-3}$

T_B= 120 N.m

2.7 Brake distance (x)

We know that tangential braking force acting at the point of contact of the brake, and

$$\text{Workdone} = F_T.* x(10)$$

Where $F_T = F_{TRI} + F_{TRO}$

x = Distance Travelled (In meter) By The Vehicle Before It Come To Rest.

We know kinetic energy of the vehicle.

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$$\text{Kineticenergy} = \frac{(mv^2)}{2} \qquad (11)$$

Where m = Mass of vehicle

v = Velocity of vehicle

In order to bring the vehicle to rest, the work done against friction must be equal to kinetic energy of the vehicle. Therefore equating (Eq. 10) and (Eq. 11)

$$F_T . x = \frac{mv^2}{2}$$

Assumption v = 100 km/h = 27.77 m/s

M = 132 kg. (Dry weight)

So we get $\mathbf{x} = \frac{mv^2}{2} / F_T$

$x = \frac{132*27.77^2}{2} / 1000$

x = 50.89 m

2.8 Non Standard Rotor disc calculation

In this case calculate same rotor disc standard but difference rotor dimension.

Table No.2.2 Brake torque & Tangential force calculation of different diameters.

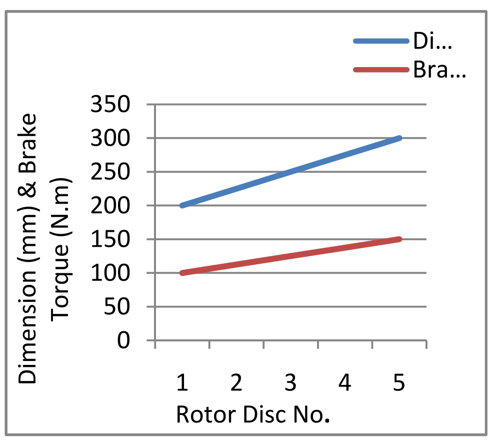
Sr. No.	Rotor Disc Dimension	F_{TRI}	F_{TRO}	F_T	T_B	X
1	300 mm	500 N	500 N	1000 N	150 N.m	50.89 m
2	275 mm	500 N	500 N	1000 N	137.5 N.m	50.89 m
3	240mm	500 N	500 N	1000 N	120 N.m	50.89 m
4	200 mm	500 N	500 N	1000 N	100 N.m	50.89 m

Forces and torque analysis on the rotor disc was studied which, are divided by tangential force, brake torque, and the motorcycle's stopping distance. The result of force value on rotor disc by tangential force and the motorcycle's stop distance are similar. When dimension of disc brake was changed, the value of brake torque was different by rotor disc dimension at 300 mm, which has the most value of brake torque, and rotor dimension at 200 mm, which has the least value of brake torque.

Table No.2.3 Relationships between Dimension of rotor disc and Brake torque.

Rotor Disc No.	1	2	3	4	5
Dimension (mm)	200	240	250	275	300
Brake Torque (N.m)	100	120	125	137.5	150

Graph 2.1 Relationships between Dimension of rotor disc and Brake torque.



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Sr. No.	Region-wise diameter (mm)		Software Result (Average Temp. in ºC)	Experimental Result (Average Temp. in ºC)
	Region	Diameter		
1	I	240-220	238.33	115
2	II	220-200	191.67	88.3
3	III	200-180	145	66.7
4	IV	180-170	98.33	43.2
5	V	170-110	51.67	25

3. Experimental Setup& Result:

Disc is rotating at constant rpm due the motor arrangement. Brake is applied periodically to reduce or to stop the disc. While applying the break the friction is takes place between the disc and friction pad. These friction forces resist to the motion of disc, due to the friction between the disc and friction pad heat is generated in the disc and it distribute over the disc

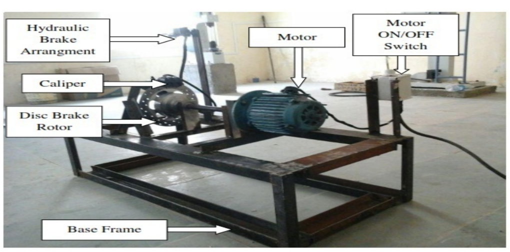

Fig 3.1Experimental Setup

The temperature at various locations is measured periodically by the non-contact type sensor such as infra-red sensor. The speed of the vehicle travel and consequently of the air circulation. Since the process of heat transfer by radiation is not too important but heat generated in the disc is dissipated by the conduction as well as convection mode of heat transfer.

Experimental Result:

Table No. 3.1 Result of original disc brake rotor

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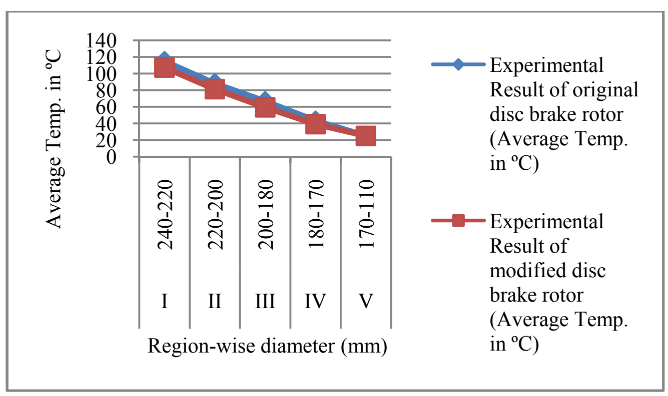
Table No. 3.1 shows the variation in temperature distribution by region-wise diameter according to software & experimental results in original disc brake rotor.

Table No.3.2Result of modified shape 4 disc brake rotor

Sr. No.	Region-wise diameter (mm)		Software Result (Average Temp. in ºC)	Experimental Result (Average Temp. in ºC)
	Region	Diameter		
1	I	240-220	226.66	107.2
2	II	220-200	168.33	81.3
3	III	200-180	110	59.4
4	IV	180-170	75	39.2
5	V	170-110	51.66	24.9

Table No. 3.2 shows the variation in temperature distribution by region-wise diameter according to software & experimental results in modified shape 4 disc brake

Graph 3.1Experimental result of original & modified shape 4 disc brake rotor



From graph 3.1 on the basis of experimental results it is clearly understand that average temperature occurs in modified shape 4 disc brake rotor is minimum as compared to original disc brake rotor.

Software Results

The highest stresses & deformations are reached at the contact surface disc pads. The rise in stresses & deformation is due to change in shape of disc brake rotor. For the four types of discs with original disc brake rotor, one notice that changes occurs in stresses, deformation & weight.

Table No.3.3 Results of Von mises, Deformation, Weight

Sr. No.	Disc Brake Rotor	Von-Mises Stresses (MPa)		Deformation (m)		Weight (Kg)
		Max.	Min.	Max.	Min	
1	Original disc brake rotor	19.083	0.00971	$3.695*10^{-3}$	0	1.052
2	Modified shape 1 disc brake rotor	19.67	0.00890	$3.829*10^{-3}$	0	1.15
3	Modified shape 2 disc brake rotor	15.291	0.022301	$3.730*10^{-3}$	0	1.207
4	Modified shape 3 disc brake rotor	27.456	0.009036	$5.3427*10^{-3}$	0	1.026
5	Modified shape 4 disc brake rotor	20.707	0.008189	$5.6881*10^{-3}$	0	0.954

4. CONCLUSION

1. The static structural & steady state analysis of disc brakes during periodic braking that performed are achieved
2. The weight of the modified shape 4 disc brake is up to 0.954 kg which is reduced about 100 grams than the original disc brake rotor.
3. Cost of the disc brake rotor ultimately reduces due to minimization of the weight disc brake rotor.
4. Stress induced in modified shape 4 disc brake rotor is 20.707 MPa which is allowable. Maximum tensile strength of cast iron is 200MPa
5. During the continuous braking process gives a different value of temperature Distribution as a result of the frictional heat generated on the rotor surface which is heat dissipated properly

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