Design and Analysis of Conventional and Perimetric Disc Brake

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Abstract - *In 21st century brake designing is an important task and companies are constantly updating and improving their designs which are safer for passengers and are quick in their response. There are some important parameters that are considered while evaluating braking performance of a vehicle which include deceleration, stopping distance and the time required to stop. This paper tries to present a new approach to designing a brake disc for two wheelers which reduces stopping distance and time with less efforts made by the rider. The performance of this disc is compared with the existing bike brake disc. Static structural and thermal analysis has been carried out on the conventional and perimetric disc to determine changes in deformation and stress along with temperature. Software's like Solidworks, Ansys have been used to design and analyze the components. After the analysis it was evident that the proposed new design was more efficient than the conventional design and had better results in all the parameters that it was tested for.*

Key Words: **— Perimetric Disc, Ansys, Solidworks, Brake Distance, Deformation, Stress**

1. INTRODUCTION

When it comes to manufacturing any vehicle brakes are a crucial part of the system and thus a lot of attention is given to the problems associated with it. Drum brakes and disc brakes are the majority of the brakes used today with disc brakes being more efficient but costly than drum brakes. A disc brake consists of brake calipers that squeeze the pair of pads against the rotating brake disc and with the help of friction the speed of rotation is reduced. They are better at managing heat and since they are open to environment convection can occur easily because of this less brake fade occurs and consistent braking is obtained. The brake pads are found to last longer than the brake shoes in the drum brakes. The disc braking system is simple and effective in its operation this leads to easy replacement of the damaged parts. However there are certain problems associated with them like brake howl, brake judder and longer braking distance. Perimetric brake disc is a new concept that aims to reduce such issues and simultaneously improve the existing qualities of disc brake.

2. LITERATURE REVIEW

Perimetric disc is bolted through its outer perimeter and the calipers are mounted from the inner perimeter of the disc. This is done so that a larger size disc can be accommodated and a lesser torque has to be worked upon. A peripheral disc brake needs less brake force for same effects, induce the remaining bending and shear stresses in wheel spokes and less radial thrust at the wheel bearing. All of these factors allow for a light weight of the wheel. Lighter weight means more efficiency, reducing unsprung mass and a higher power to weight ratio.

It was observed that peripheral disc brakes needed less brake force for producing the same end effect, and they induce lesser bending and shear stress in wheel spokes and also very lesser radial thrust at the wheel bearings. Thus all these factors allow for making a very light weight motorcycle front wheel. Having less weight means more efficiency, reduced unsprung mass and a higher power to weight ratio. [1]

Tanuj Joshi et al conducted a study on perimetric brake disc and concluded that perimetric brake disc was much better than conventional brake disc as it increased the deceleration of vehicle, decreased stopping distance of vehicle, decreased the stopping time and was structurally and thermally safe. [2]

Vivek A. Kamble et al in their experimentation found out those perimeter disk brakes provide larger braking radius, less braking distance, relatively less slip percentage and more surface area for dissipation and better stability as compared to conventional disk brakes. [3]

Ms. A. J. Padwal et al designed an approach to resolve the variance of the design space without disturbing the design of the wheel rim and the experimentation was carried out on Pulsar 150 cc bike's front wheel. From the analysis of both perimetric and conventional disc it was found out the stresses and temperature induced in the perimeter brake system are much less as compared to the conventional disc brake system and thus it was understood the time and distance required to stop the vehicle in the perimetric system was less with the same efforts in the conventional system. [4]

Brake noise is caused due to the vibrations of the brake during braking. If the friction force between friction pads and brake disc varies then it can cause brake discs to vibrate at different frequencies and also make brake noise. In this paper the Brake Torque Variation (BTV) is considered by the author the main reason for the vibrations produced. The author suggests changing of friction plate and structure design along with careful selection of brake friction parts to attenuate the brake noises [5].

3. ANALYSIS METHODOLOGY

Modeling of brake rotor

The conventional and peripheral brake rotor model for the front wheel was completely designed on Solidworks. The sketch command was used to design a 2d sketch by using various geometrical commands. Then the sketch was converted into 3D design by extrude command and various other features were added to the disc model.

Meshing

A finite element-based software ANSYS is used. The discretized FEA models of the conventional disc and periphery disc are shown in Fig.1 and Fig.2, respectively. It contains 31516 nodes and 12464 elements on the peripheral rotor and 81691 nodes and 56623 elements on the conventional rotor

Design Specifications

For this study, the Yamaha R15 bike was selected and the following table shows the specification of the braking system [2,6]

Table -1: Specifications

Parts	Front (conventional)	Front (Perimetric)
Master Cylinder Diameter	11	11
Piston Caliper Diameter	25.40 (Dual Piston)	25.40 (Single Piston)
Pedal Ratio	5:1	5:1
Tire Diameter	575.9 mm	575.9 mm
Disc Diameter	267 mm	380 mm
Disc Thickness	4 mm	4 mm
External Diameter of Rubbing Surface	265 mm	380 mm
Internal Diameter of Rubbing Surface	210 mm	325 mm
Friction Length of Pads	61.5 mm	61.5 mm
Number of pads	2	2
Caliper	1	1

Fig -1: Conventional Disc

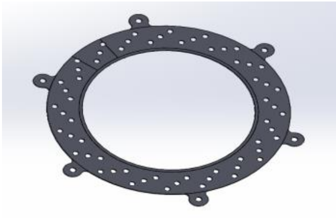

Fig -2: Perimetric Disc

4. CALCULATION

The governing calculations required to perform the analysis are given as follows:

External parameters required for the calculations are:

Initial Velocity = 120 kmph = 33.33 m/s^2

Stopping Distance (s) = 100 m

Mass of vehicle along with driver = 200 kg

v= Initial Velocity (m/s)

u= Final Velocity (m/s)

a= Acceleration (m/s^2)

t= Time (seconds)

T= Total Time (seconds)

$K.E_1$= Kinetic Energy Initial (J)

$K.E_2$= Kinetic Energy Final (J)

W= Work Done (J)

Using Newtons Laws of motion, Calculating Deceleration (a):

$2as= v^2-u^2$

$2*a*100 = 33.3^2 -0^2$

a = 5.55 m/s^2

Calculating stopping time taken (t)

v = u + a*t

0 = 33.33-5.55* t

t = 6 sec

For Conventional Front Disc

Braking force (F_b)

$K.E_2-K.E_1= W$

$12*0.72\ M\times V^2 = F_b*s$ .... (Brake bias is 72:28)

F_b = 799.84 N

Torque required to stop the wheel (T)

T= F_b *radius of wheel

T= 799.84*(0.575)/2

T=229.954 Nm

Force on Brake Disc (F_d)

F_d= T/ (radius of disc * μ) ...... (μ pads = 0.4)

F_d = 4306.25 N

Pressure created by piston (P)

A = Area of 1 piston caliper

P= F/2A

P= 4.249 MPa

Force applied by master cylinder to get the required pressure (F_c)
A= Area of master cylinder piston
F_c= P*A
F_c= 403.81 N

Since the pedal ratio is 5:1
The force applied by human (F_h)
$F_h = (F_c*1)/5$
F_h = 80.76 N
Mean right hand brake force by humans is 78.66 N [7]

For Perimetric Front Disc
Braking force (Fb)
$K.E_2 - K.E_1 = W$
$12*0.72\ M*V^2 = F_b*s$
F_b = 799.84 N

Torque required to stop the wheel (T)
T= F_b * radius of wheel
T= 799.84*(0.575)/2
T=229.954 Nm
Force on Brake Disc (F)
F= T/ (radius of disc * μ) …... (μ pads = 0.4)
F= 229.954/ (0.19 ×0.4)
F = 3025.71 N

Pressure created by piston (P)
A = Area of 1 piston caliper
P= F/2 A
P= 3025.71/ (2 *506.707)
P= 2.985 MPa

Force applied by master cylinder to get the required pressure (Fc)
A= Area of master cylinder piston
F_c= P*A
F_c= 283.68 N

Since the pedal ratio is 5:1
The force applied by human (F_h)
F_h= 283.68/5
F_h= 56.73 N
Mean right hand brake force by human is 113.46 N [7].

4.1 Material

Material used for front disc is Cast Iron as it is characterized for its efficient thermal conductivity and anti-vibration capacity. Following are the properties of Cast Iron [8]

Table -2: Materials Properties

Material Properties	**Values**
Density	7.15E-06 kg/mm³
Young's Modulus	120500 MPa
Poisson's Ratio	0.3
Yield Strength	758 MPa
Thermal Conductivity	0.021 W/(mm K)
Thermal Expansion Coefficient	1.2E-05 /K
Specific Heat	450 (kg K)

4.2 Operating Conditions

The operating parameters for the study are set according to the Table -3:

Table -3: Operating conditions

Temperature ambient	20 °C
Stopping time	7 seconds
Convection value	38 W/(m² K)
Gravity	9.81 /s²

5. ANALYSIS

Static and thermal analysis were performed on the models of the brake discs using the calculated forces and pressure applied on the discs, material and operating conditions as given in Table 2 and Table 3

5.1 Static structural analysis

Static analysis is performed over a structure to check if it can withstand the applied external loads under static conditions. During the analysis loads and boundary conditions are applied gradually.
Solving Model

- Total Deformation
- Von Mises Stress

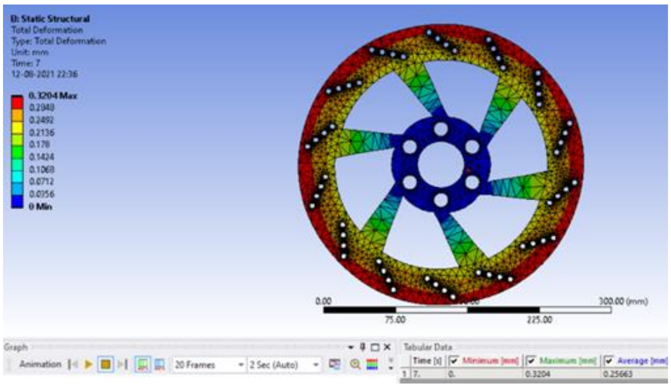

Fig -3: Total Deformation of conventional disc

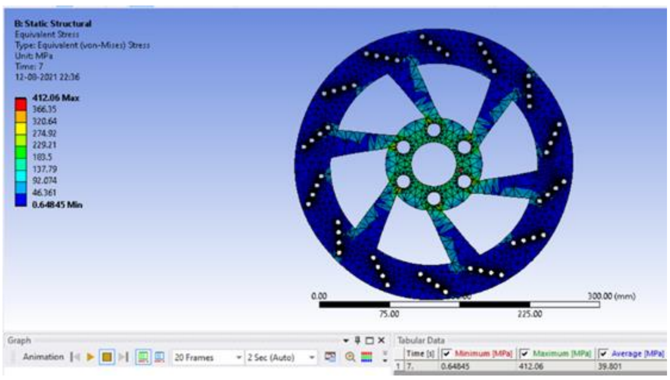

Fig -4: Equivalent (von-Mises) stress for conventional disc

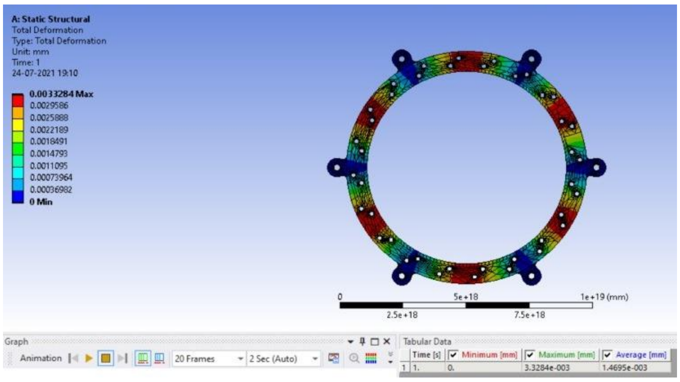

Fig -5: Total Deformation of Perimetric disc

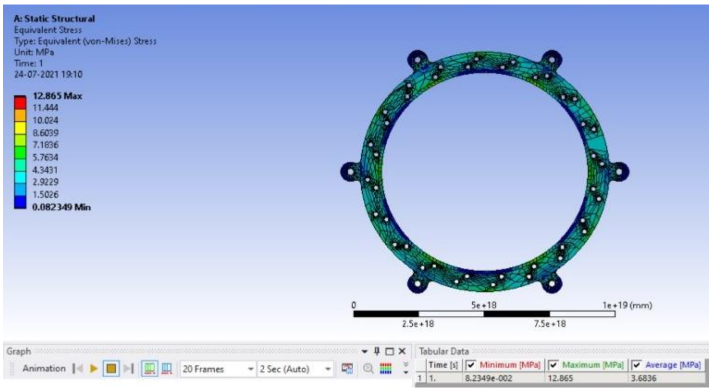

Fig -6: Equivalent (von-Mises) stress for Perimetric disc

5.2 Thermal analysis:

Thermal analysis is performed to determine what effect will be observed on the model surface under extreme temperature and pressure by assigning the model required constraints.

Solving Model

- Temperature Change
- Heat Flux

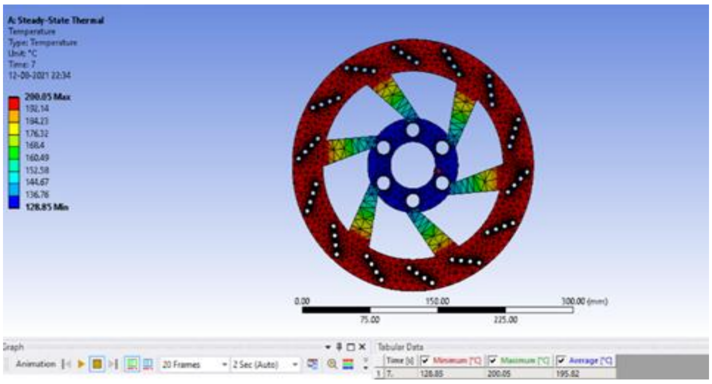

Fig -7: Temperature for conventional disc

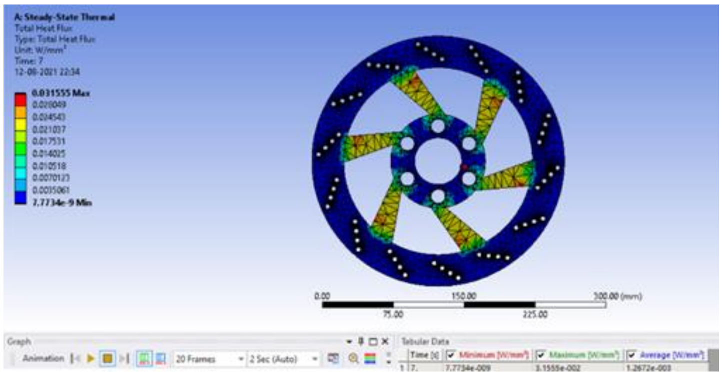

Fig -8: Total heat flux for conventional disc

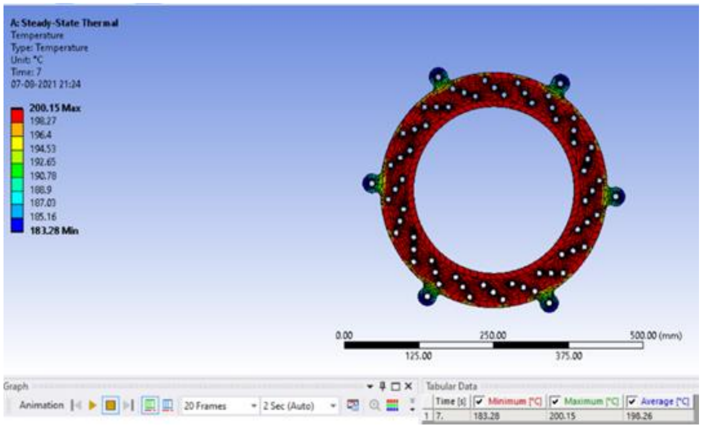

Fig -9: Temperature for perimetric disc

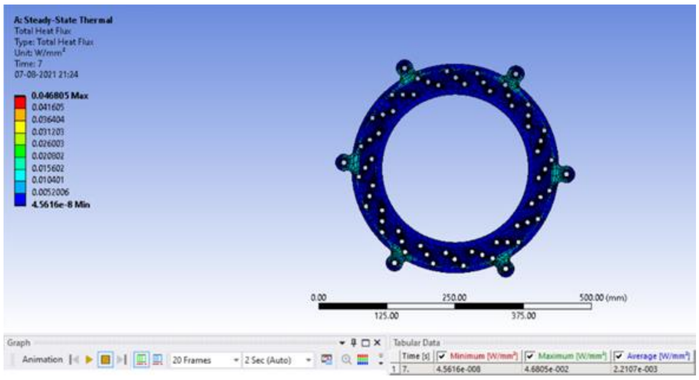

Fig -10: Total heat flux for perimetric disc

6. RESULTS

The vehicle was assumed to be moving at a speed of 120 kmph before applying the brakes. To comprehend the deformation and stresses developed in both the type of disc models after the application of forces and pressure, a static analysis was performed on Ansys software. A force of 4306.25N and pressure of 4.38MPa was applied on the conventional disc while a force of 3025.71N and pressure of 2.98MPa was applied on the perimetric disc.

Table -4: Conclusion of the study

Parameter	Conventional		Perimetric	
	Max	**Min**	**Max**	**Min**
Deformation	0.32mm	0	0.0033mm	0
Von Mises Stress	412.06MPa	0.648 MPa	12.865 MPa	0.08 MPa
Temperature	200.5 °C	128.5 °C	200.15 °C	183.28 °C
Heat Flux	3.15E-02 W/mm^2	7.77E-09 W/mm^2	4.68E-02 W/mm^2	4.56E-08 W/mm^2

7. CONCLUSIONS

The study in this paper has shown that the use of perimetric disc instead of the conventional disc results in less requirement of the human effort to stop the vehicle and also the distance required for stopping reduces. The perimetric disc has less deformation and stresses under the applied load which leads to more lifespan of the disc. Perimetric brake disc can be a good alternative to the conventional discs because of their larger radius and more surface area for heat dissipation ultimately giving better stability during braking.

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