DESIGN, ANALYSIS AND CHARACTERIZATION OF PERIPHERAL DISC BRAKE SYSTEM FOR MOTOR CYCLE FRONT WHEEL

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ABSTRACT

In current days speed and torque requirement of automobiles is increasing day by day. As we know, not only speed and torque is a requirement of the automobile designers but also the braking and comfort without skidding of vehicle is also a primitive parameter. The interest of the project is to avoid accidents and noise free braking with less chances of failure. A capable braking system plays an essential role when vehicle has to run at superior speeds. The conventional disc brake is not so much efficient to bring the vehicle at stop within a shorter distance. The Perimeter brake design arrangement is a very efficient resolution for different vehicles to overcome the above deficiencies. An approach to resolve the variance of the design space without disturbing the design of the wheel rim, tangential brake constructions is recommended. These are known as perimeter disc brake. In the current design perimeter disc design is carried out for Pulsar 150 cc bike for front wheel. Experimental investigation of the same disc is carried out by developing laboratory experimental setup which will give the stopping time as output for conventional and peripheral disc brake system.

From the analysis is found that the stresses and temperature induced in the perimeter brake system are much less as compared to the conventional disc brake system. From the experimentation it is clear that the time required to stop the vehicle is much less with perimeter disc with the same efforts which were required to stop the wheel with conventional braking system.

Key words: Two Wheeler Geared Vehicle, Conventional Disc Brakes, Peripheral Disc Brakes, Computational analysis.

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1. INTRODUCTION

A disc brake is a type of brake that uses calipers to squeeze pairs of pads against a disc in order to create friction that retards the rotation of a shaft, such as a vehicle axle, either to reduce its rotational speed or to hold it stationary. The energy of motion is converted into waste heat which must be dispersed. Hydraulic disc brakes are the most commonly used form of brake for motor vehicles but the principles of a disc brake are applicable to almost any rotating shaft. Compared to drum brakes, disc brakes offer better stopping performance because the disc is more readily cooled. As a consequence discs are less prone to the brake fade caused when brake components overheat. Disc brakes also recover more quickly from immersion (wet brakes are less effective than dry ones). Most drum brake designs have at least one leading shoe, which gives a servo-effect. By contrast, a disc brake has no self-servo effect and its braking force is always proportional to the pressure placed on the brake pad by the braking system via any brake servo, braking pedal, or lever. This tends to give the driver better "feel" and helps to avoid impending lockup. Drums are also prone to "bell mouthing" and trap worn lining material within the assembly, both causes of various braking problems.

In disc brake, brake calipers are used to grip pairs of pads against a disc. With the help of which friction is generated against the brake pads and the disc surface which retards the rotation of the wheel or vehicle axle, either to minimize its speed or to stop the rotations of the wheel. Compared to drum brakes, disc brakes offer better stopping capability because the braking force acts in axial direction whereas drum brake braking force acts in radial direction. The heat generated due to the friction between the calipers and disc surface is dissipated quickly in the disc brake as compared to the drum brake. Even having more stopping feature as compared to drum brake, disc brake have some dis-advantages such as brake howl, break judder, breaking distance. To overcome these drawbacks, perimeter disc is one of the solutions for it.

2. PROBLEM STATEMENT

i. For two wheeler front wheels, braking system requires large manual force to stop the vehicle. So, there is a requirement to decrease the braking force.
ii. When rider applies the brake, the vehicle which is running at very high speed, it is required to stop the vehicle within a short distance which is not possible with conventional disc brake system. So there is a need to design a new brake disc system which can stop the vehicle without skidding and within a short distance.

3. OBJEVTIVES

i. Is it required to design a peripheral brake disc system and needs optimize it for the weight reduction.
ii. For the optimized peripheral disc it is required to check stresses developed at the braking load condition for the safety of the disc and the heat dissipated with the help of analysis tools such as ANSYS.
iii. Experimental testing of the conventional disk brake system is to be done to determine braking distance and brake power absorbed at various vehicle speeds.
iv. Experimental testing of the perimeter disk brake system is to be done to determine braking distance and brake power absorbed at various vehicle speeds.

4. METHODOLOGY

Step 1. Literature Review Regarding Concerned Topic: Data collection and selection of material for project from reference paper and from different technical sites.
Step 2. Component Design: In which system is design and also develop with the point of operation.
Step 3. Mechanical Design: It is related to find out what kind of forces and stress are acted on project object. The slandered parts have been selected from PSG design data handbook.
Step 4. Production Drawing Preparation: Production drawing of the parts is prepared using auto-cad and cattie v-5. With the appropriate dimension and geometric tolerance.
Step 5. Analysis of Project Model: Analysis of project model is done by using ansys-17. In which static-structural and steady-state thermal analysis is carried out.
Step 6. Material Procurement & Process Planning: Material is procured as per raw material specification and part quantity. Part process planning is done to decide the process of manufacturing and appropriate machine for the same.
Step 7. Manufacturing: Parts are produce as per the parts drawing.
Step 8. Assembly As Well, As Test & Trial: Assembly has been done according to concept and test and trial is conducted on device for evaluating performance.
Step 9. Conclusion: It include comparison of both project model i.e. existing and the new one And finally reach up to the mark that which one is the best.
Step 10. Report Preparation: Report preparation activity has been done after all above steps once carried out.

5. DESIGN OF CONVENTIONAL AND PERIPHERAL DISC

Design of Peripheral Disc:
Braking torque calculation
Power of Bajaj pulsar 150 cc is 14 HP
P_1 = 14 HP (Brake horse power)
= 14×0.746 kW

= 10.4444 kW

This is the brake horse power of the engine. Now considering the losses due to rolling resistance offered by tire and transmission losses we have to calculate power at the front wheel. Power losses due to rolling resistances are 10% of available power.

Considering the worst condition for design of front disc we are applying only front brakes.

Power available considering rolling resistance = 0.9 × 10.444

= 9.3996 kW

Considering transmission efficiency 90% for the motorcycle

Available power will be,

Net power = 0.9 × 9.3996

= 8.3459 kW Eq.(1)

We know while braking when the brakes are applied the work will be done against the available power

Power = Work done for stopping the vehicle

So we know work done by the brake disc is rotational work done.

Work done = T ω Eq. (2)

ω = Angular velocity of wheel

$$\omega = \frac{2\pi n_2}{60}$$

$$= \frac{2\times\pi\times1140}{60}$$

= 119.38 rad/s

Now we know equation (1) is equal to (2)

$P_1 = T\,\omega$ (Ref. number 13)

$$T = \frac{P_1}{\omega}$$

$$= \frac{8345.9}{119.38}$$

T = 69.91 N-m

Designation	Ultimate Tensile Strength, N/mm^2	Yield Strength, N/mm^2
Grade 410	460	415

Table.5.1 Material of Disc

Below figure shows the 2D drawing of the conventional brake disc (left) and Peripheral Brake Disc (Right).

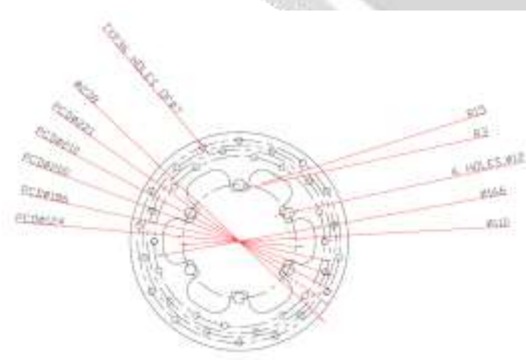


Fig. 5.1 2D Sketch of Conventional Brake Disc

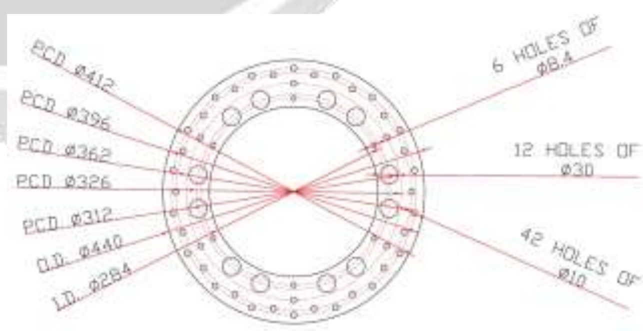


Fig.5.2 2D Sketch of Peripheral Brake Disc

Calculations of Heat Flux for Thermal Analysis:

Heat Flux = $\frac{\text{Heat Generated due to friction}}{\text{Area of the brake pads}}$

Heat generated due to friction can be calculated as the work done against the power of the vehicle to stop. We have, at worst condition brake power available considering tyre friction loss and transmission loss is 8345.9 watts (considering all losses).

So, Power lost in friction = $\mu \times \text{Brake power available considering all losses}$

Where, $\mu = 0.45$, coefficient of dry fricion

And Brake power available considering all losses = 8345.9 Watts.

Therefore, Power lost in friction = 0.45×8345.9 = 3755.655 Watts.

Now, suppose the vehicle which is running at 120 kmph and stops within 10 seconds after application of the full braking load.

So, the total brake power which is available has to be converted into the frictional work done in ten seconds.

Therefore, frictional work done = $\frac{\text{Power lost in friction}}{\text{time}}$

$= \frac{3755.655}{10} = 375.56$

Therefore, Heat Flux = $\frac{375.56}{2135.78 * 2}$ W/mm^2 (Denominator multiplied by 2 as two brake pads are present)

= 0.087922 W/mm^2

Heat Flux = 87922 W/m^2

6. COMPUTATIONAL ANALYSIS

Structural and thermal analysis of the brake disc is carried out in Ansys 16.0. The tetrahedral mesh element is used for meshing of the disc with patch independent method. The statistics of the nodes and elements is given as below.

Discretization of the conventional brake disc to carry out the structural analysis is done. Meshing of the conventional brake disc is carried out in Ansys software. Above figure shows the meshed model of the conventional brake disc. The statistics of the number of nodes, number of elements, average element quality, element type, and element size is discussed further as shown below table. The mesh model of the conventional brake disc and peripheral brake disc is as shown below.

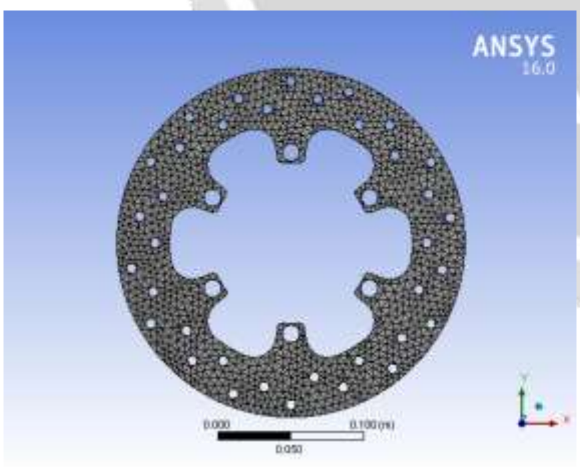


Fig. 6.1 Mesh Model of conventional brake disc

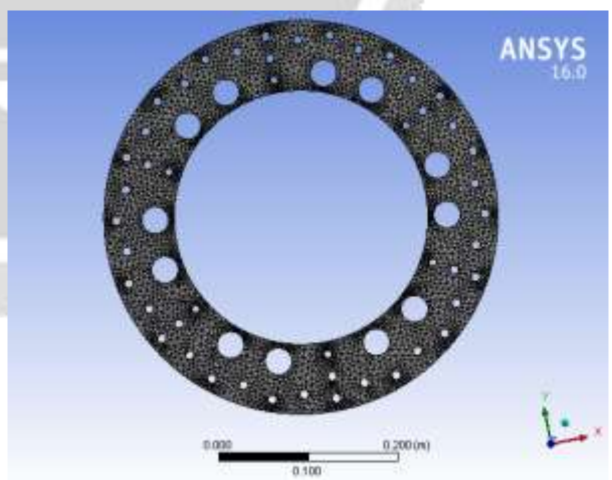


Fig. 6.2 Mesh Model of peripheral brake disc

Mesh Statistics and Element Quality:

Particulars	Conventional Brake Disc	Peripheral Brake Disc
Nodes	24340	60019
Elements	13272	31649
Average Element Quality	0.66542	0.737
Element Type	Tetrahedrons	Tetrahedrons
Element Size	6 mm	6 mm

Table.6.1. Mesh details of the conventional brake disc and peripheral brake disc

Boundary conditions:

Boundary conditions for the brake disc are assigned as the braking torque of 69.91 Nm and fixed supports at the bolted joints where the disc is mounted on the wheel hub/spokes is assigned.

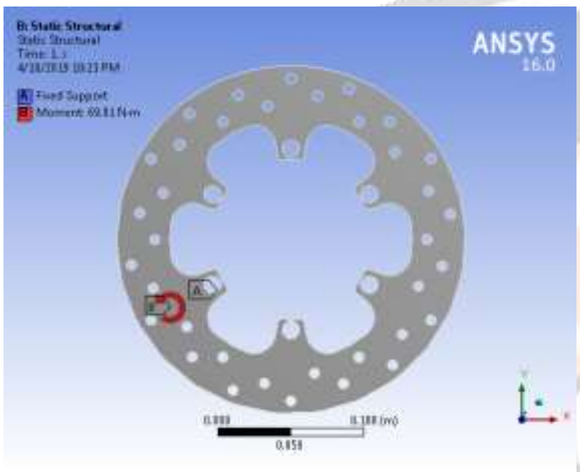


Fig. 6.3 Boundary conditions for conventional brake disc

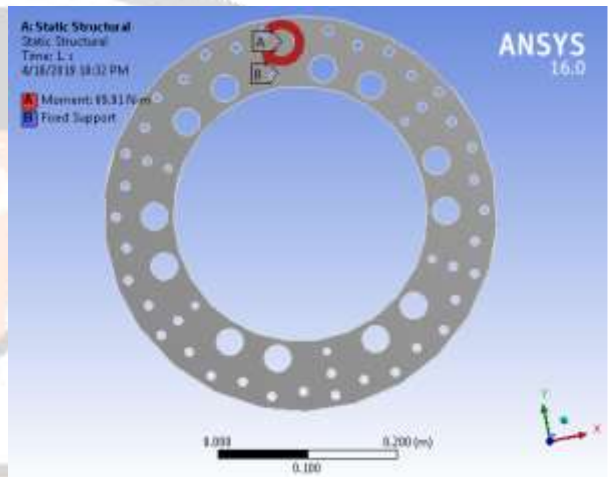


Fig. 6.4 Boundary conditions for peripheral brake disc

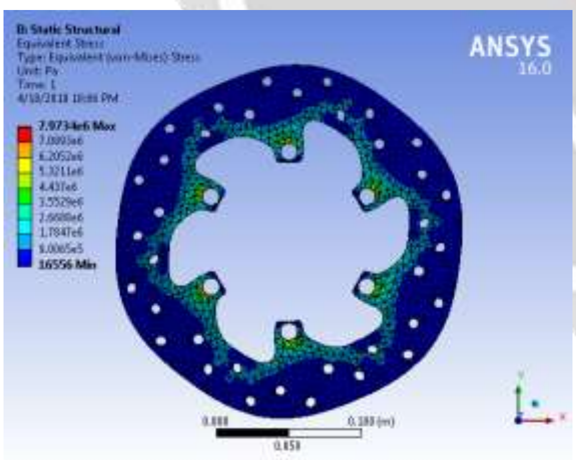


Fig. 6.5 Von-Misses stress for conventional brake disc

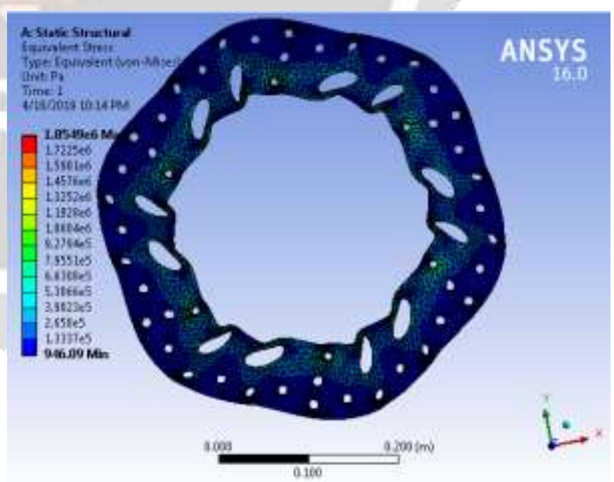


Fig. 6.6 Von-Misses stress for peripheral brake disc

From the analysis of the conventional brake disc and peripheral brake disc it is found that the maximum stress developed is 7.93 MPa and 1.8549 MPa respectively, which is much less as compared to the maximum tensile strength of the disc material.

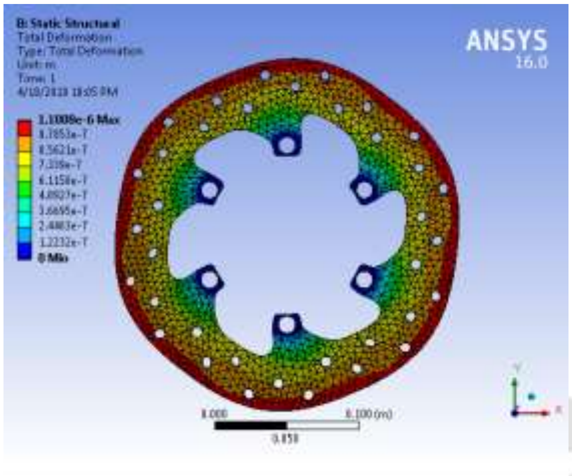


Fig. 6.7 Total deformations for conventional brake disc

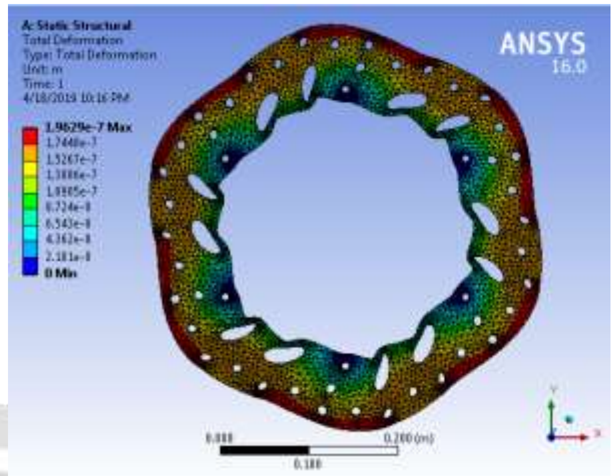


Fig. 6.8 Total deformations for peripheral brake disc

From the analysis of the conventional brake disc and peripheral brake disc it is found that the maximum deformation occurred is 0.0011 mm 0.19 µm only.

Summary of Analysis with Comparison of FEA Results:

Particulars	Conventional Brake Disc	Perimeter Brake Disc
Total Deformation	0.0011 mm	0.0001962 mm
Von Misses Stress	7.9724 MPa	1.8549 MPa

Table.6.2 Summary of structural analysis

From the above analysis it is seen that with the use of peripheral disc brake system the stresses developed are minimized by 76.7 per cent with respect to the conventional disc brake system and the total deformation is decreased by 82 per cent.

Thermal Analysis of Brake Discs:

Boundary Conditions:

Boundary conditions for the thermal analysis are given as below,

Heat flux: 87922 W/m^{2,} Radiation through all the faces of the disc at room temperature and convection throgh all faces of the disc at 234 W/m^{2} °C.

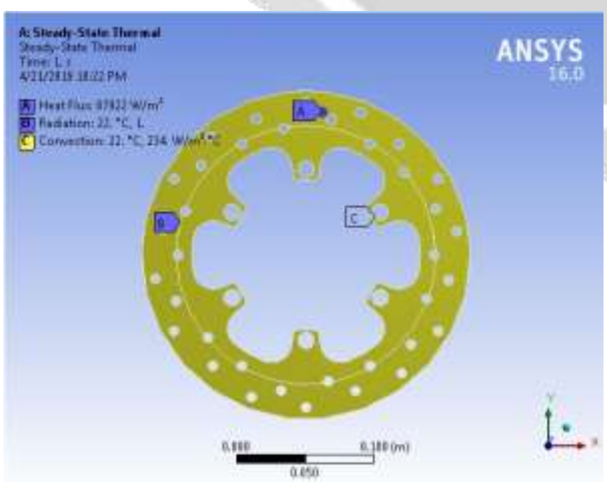


Fig.6.9 Boundary Conditions for Conventional Brake Disc

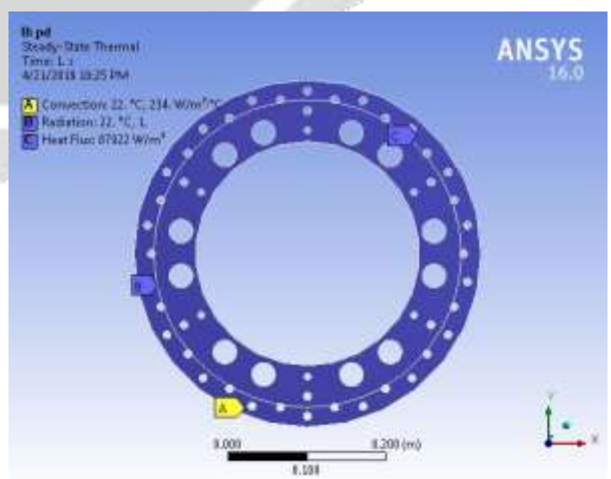
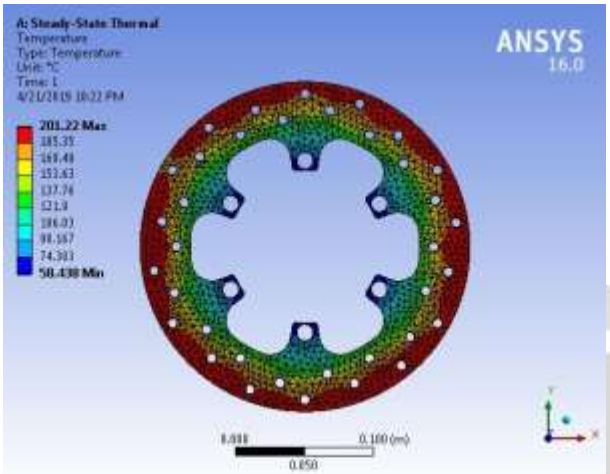


Fig.6.10 Boundary Conditions for Peripheral Brake Disc

Above figure shows the boundary conditions assigned to the conventional brake disc. Notation 'A' shows the heat flux data, notation 'B' in the figure shows heat dissipation though radiation and notaion 'C' shows the heat dissipation through convection heat transfer.



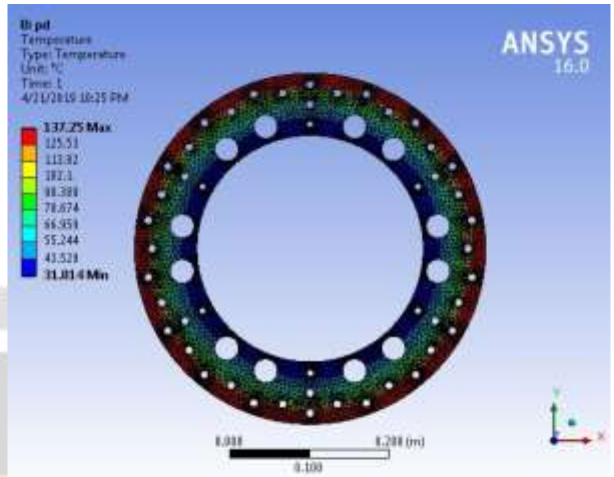
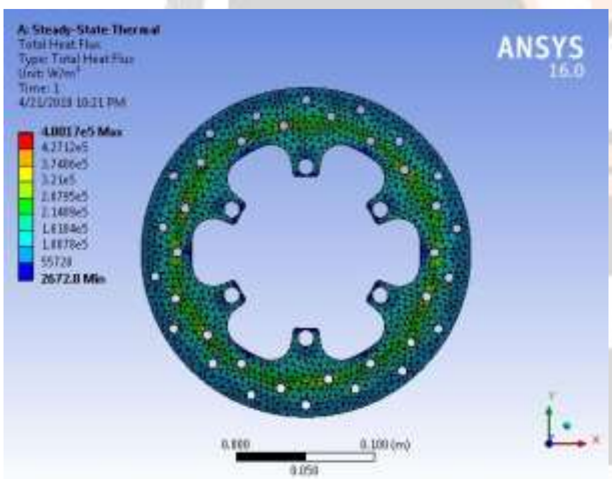


Fig.6.11 Temperature observed in Conventional Brake Disc **Fig.6.12**Temperature observed in Peripheral Brake Disc

Above figure shows the maximum temperature observed at conventional brake disc surface is 201.22 degree Celsius in the brake liner contacting region. Whereas for peripheral brake disc, temperature observed is 137.25 degree Celsius. This temperature is observed for very short time as the disc is in continuous rotation mode. The temperature will be dissipated through the non-contacting regions of the brake liners when disc is in rotation mode.



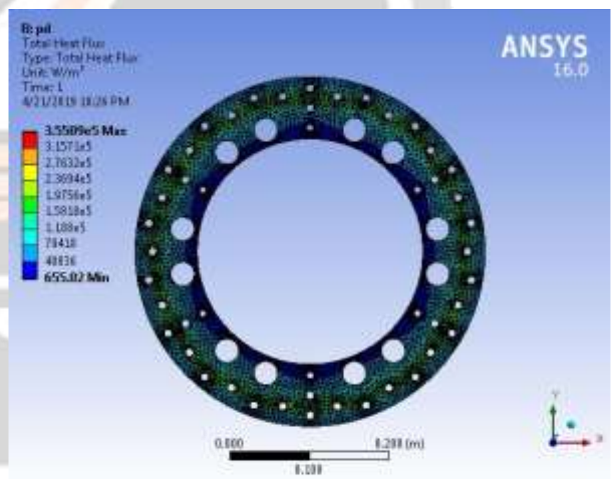


Fig.6.13 Total Heat Flux induced Conventional Brake Disc **Fig.6.14**Total Heat Flux induced Peripheral Brake Disc

Total heat flux induced in the conventional brake disc is obeerved to be 4.801e5 W/m2. And total heat flux induced in the conventional brake disc is obeerved to be 3.5509e5 W/m2.

Comparative observations of thermal analysis

Sr. No.	Temperature ($^{\circ}$C)	Heat Flux (W/m^2)
Conventional Brake Disc	201.22	4.8017e5
Peripheral Brake Disc	137.25	3.5509e5

Table.6.3 Comparative observations of thermal analysis

From the analysis it can be seen that the maximum temperature observed in the conventional brake disc is 201.22 and for peripheral brake disc 137.25 which is 31.79 per cent decrement in the induced temperature due to friction. This temperature induced is decreases due to increases surface area of the peripheral disc brake. Also total heat flux mount is decreased by 26.05 per cent.

7. EXPERIMENTAL ANALYSIS

Experimental Setup

Fig.7.1 Assembly Set-Up

Procedure for Experimentation

1. Initially without applying nay braking load start the motor and let the wheel rotate for some time idle.
2. Weight till the tachometer shows constant readings on the display which may seems that the shaft is running at constant rpm.
3. Note down the speed of shaft at no load condition.
4. Now, to measure the time required for braking keep the timer ready.
5. To stop the wheel, we need to gradually apply the braking load and record time required to stop the wheel. Normally, the braking load applied by the riders on the brake lever is with the help of hand. Means, the amount by which rider presses the brake level, that much amount will be the braking load.
6. So, in the experimental test rig, if directly we apply the load with the help of hand on lever, every time it may not come the same loading condition. So, to avoid the error in application of the load, we are applying the braking load with the help of dead weight which may results for ease in calculation and accuracy.
7. Load the weighing pan by 2 kgs of dead weight and start recording the time required to stop the vehicle.
8. The rotating wheel will start to retard and finally come to rest that is rpm will be zero. Stop the timer and note down the time required.
9. Now, remove the weight from the loaded weighing pan and let the wheel to rotate till it reaches the constant rpm. Now repeat the same procedure by adding dead weights at different braking load conditions and record the time.
10. The trials are carried out and the measured data is discussed further.

Test and Trial Disc Brake:

The procedure discussed above is carried out and the data is recorded at different braking load conditions for conventional brake disc as well as for the peripheral brake disc system. The recorded data is discussed further in the table and graph format.

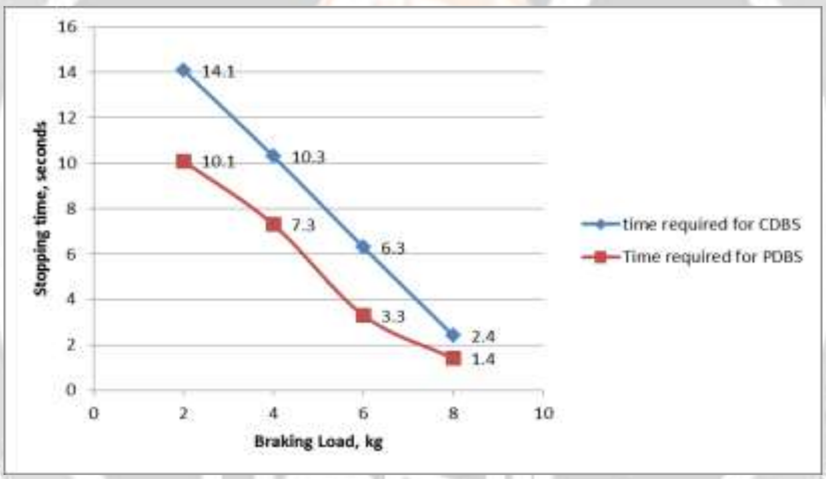
Sr. No.	Rpm measured without application of brakes, rpm	Load applied for stopping the wheel, kg	Time required to stop the wheel, seconds	Stopping distance in meters
1.	1021	2	14.1	421.2
2.	1021	4	10.3	307.69
3.	1021	6	6.3	188.2
4.	1021	8	2.4	71.69

Table.7.1 Observation table for conventional disc brake

Sr. No.	Rpm measured without application of brakes, rpm	Load applied for stopping the wheel, kg	Time required to stop the wheel, seconds	Stopping distance in meters
1.	1021	2	10.1	301.6
2.	1021	4	7.3	218.1
3.	1021	6	3.3	98.5
4.	1021	8	1.4	41.8

Table.7.2 Observation table for peripheral disc brake

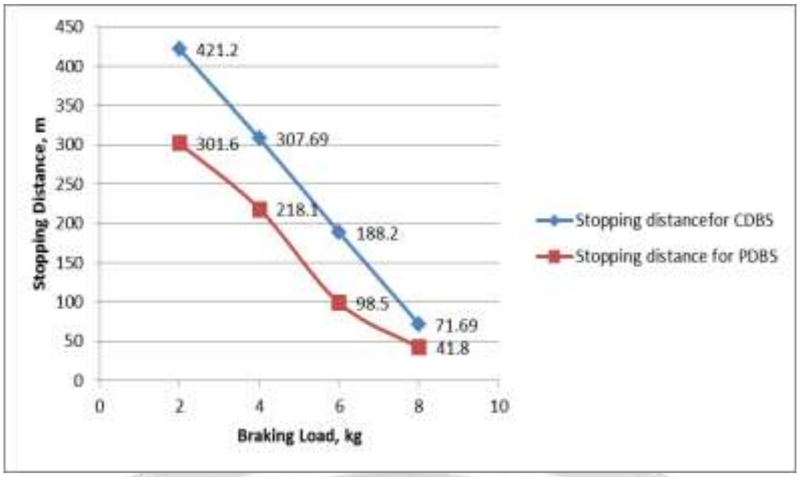
Graph showing the comparison between conventional and peripheral disc brake stopping time with respect to applied braking load:



Graph.7.1 Braking load vs Stopping time

Above figure shows the graph of braking load verses stopping distance. The blue line indicates the time required to stop the wheel for conventional disc brake system with respect to the applied braking load in the loading pan. Whereas the red line indicates the time required to stop the wheel by the peripheral/perimeter brake disc system with respect to the applied loading condition. The data is measured for conventional and peripheral brake disc system by applying the same loading conditions in both the cases. From the above graph it is seen that at every instance the time required for the peripheral brake disc to stop the wheel is less as compared to time required for conventional disc brake system at the same braking load.

Graph showing the comparison between conventional and peripheral disc brake stopping distance with respect to applied braking load:



Graph.7.2 braking load vs Stopping distance

From the time required to stop the wheel at different loading conditions are recorded in the experimental procedure for both the conventional as well as for the peripheral/perimeter disc brake system. So, with the help of standard correlation between speed, time and distance, distance travelled by the wheel is calculated and s plotted. From the graph it seems that the distance travelled by the wheel after application of the braking load in case of the perimeter disc brake system is always less as compared to the distance travelled by the wheel after application of the braking load in case of the conventional disc brake system.

8. CONCLUSION

i. Peripheral brake disc is designed by benchmarking the brake discs of the current conventional brake disc design geometries. It is seen that optimized brake disc has considerable reduction in the weight of the disc as compared to the initial model.

ii. From the FEA analysis it is seen that with the use of peripheral disc brake system, the stresses developed are minimized by 76.7 % with respect to the conventional disc brake system and the total deformation is decreased by 82%

iii. From thermal analysis it can be seen that the maximum temperature observed in the conventional brake disc is 201.22 and for peripheral brake disc 137.25 which is 31.79 % decrement in the induced temperature due to friction. This temperature induced is decreases due to increases surface area of the peripheral disc brake. Also total heat flux amount is decreased by 26.05 %.

iv. From the experimental analysis, it is seen that the time required to stop the vehicle with conventional disc brake system is 14.1 seconds with least braking load.

v. For peripheral disc brake system, time required to stop the vehicle with the same load (which was used with conventional disc brake system) is 10.1 seconds. So, it can be concluded that the time required to stop with peripheral disc brake is 28.36 % less than that of the conventional disc brake system.

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