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 to avoid accidents and noise free braking is also the high priority. A capable braking system plays an essential task when vehicle has to run at superior speed. The conventional disc brake is not so much efficient to make the vehicle speed to an end within a shorter distance. The Perimeter brake design arrangement is a very efficient resolution for different vehicles. 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.

Keywords: - *Two Wheeler Geared Vehicle, Conventional Disc Brakes, Peripheral Disc Brakes, Computational analysis.*

1. INTRODUCTION

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 where as 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 disadvantages such as brake howl, break judder, breaking distance. To overcome these drawbacks, perimeter disc is one of the solutions for it.

1.1 Problems in Conventional Disc Brake

Brake Squeal:

When the brakes were applied a strident noise or high pitched squeal occurs. Most of the time, brake squeal is generated when the frequency of vibrations matches with the natural frequency of the brake components, especially the pads and discs. This type of squeal may affect negatively on brakes and consequently reduces stopping performance. In the winter due to cold weather and humidity, in early morning we observe frequently worst brake squeal, and the squeal generally stops when the brake lining or pads surface reaches regular operating temperatures. Dust particles also may cause squeal and industrial brake cleaning products are intended to remove dirt and other contaminants.

Brake Judder:

Brake judder is the vibrations experienced by the driver from negligible range to harsh vibrations which were transferred through the chassis during braking. Hot judder is usually produced due to continuous extreme braking to make the speed of the vehicle to zero or directly to stop the vehicle from a very high speed which intern transmits harsh vibrations to the driver. These vibrations occurrence is due to uneven thermal distributions, or hot spots. Hot spots are concentrated thermal regions which is present between both sides of a disc that deform it in such a way that produces a sinusoidal waviness near its edges. When the brakes were applied and the brake pads come in contact with the sinusoidal surface, extreme vibrations are generated, and can produce unsafe conditions for the person driving the vehicle.

2. PROBLEM STATEMENT

The main problem in the conventional disc braking was the braking efficiency. As soon as the driver applies the brakes with less effort then within shorter distance the vehicle should stop without making any noise such as brake squeal and brake judder condition.

3. OBJEVTIVES

To design the brake which can stop the vehicle or which can reduces the speed of the vehicle with less pedal/lever efforts and within a shorter distance.

4. METHODOLOGY

Step1. Initially literature survey is carried out for the probable solution for the above problem.
Step2. In the design, initially comparison wise theoretical analysis is carried out for the conventional brake disc and the new perimeter brake disc concept.
Step3. As per the availability of the wheel rim peripheral thickness the brake disc is designed so that drilled holes can be made at the periphery of the disc for mounting the brake disc.
Step4. CAD model of the designed brake discs are made for the computational analysis to check the safety of the designed brake discs.
Step5. Manufacturing of the peripheral brake disc is done and experimental setup is made accordingly to validate the results of theoretical and computational analysis and comparative results of experimental analysis are plotted.
Step6. Conclusion of the above research is summarized with respect to the results obtained.

5. LITERATURE SURVEY

Shivankur Mittal Et. Al. for the lighter weight front wheel vehicles the inside out disc along the rim can give the best results for the braking end effects. It will induce less bending and shear stresses in the wheel assembly. The So called peripheral brake system also produces less radial thrust at the wheel bearing [1].
Heidrich, Lukas, Augsburg Et. Al. tells about how to overcome the bottle necking ofdesign space constraint for the conventional disc brake design, perimeter disc brake constructions can be used. The focus of this paper are to check properties of perimeter disc brake systems for use during on-brake and off-brake periods, and investigation of scaling effects on these properties due to the principle of this brake [2]. **Crowe, P**Et. Al. research says the brake disc which is larger in diameter provides larger surface area for braking and heat dissipation which intern increases braking efficiency. The perimeter brakes can be very effective as compared to conventional disc brakes [3]. **EmanueleToson, Brakko**Et. Al. tells disc brake, preferably for motorcycle front Wheels, with use of peripheral annular disc arranged in such a way that its brake caliper reaction force passes through a fixed axle which is coaxial with the wheel. The brake caliper is mounted at the end of a steering fork which is rigidly connected to the axle [4].
Li Jin, XuJianchang, Luo Fang Et. Al. tells about the brake noise and vibration generated during braking. Variation in the friction force between pads and brake disc can cause the brake disc to vibrate at different frequencies and will produce different brake noise. In this paper, the author considers that Brake torque variation (BTV) is the main cause of brake vibration and brake noise. Research also says that, not only just replacing the friction plate but can decrease the vibrations but also we should change the structure design and careful selection of brake friction parts in order to minimize brake noise [5].

6. THEORETICAL ANALYSIS WITH RESPECT TO ADVANTAGES AND DISADVANTAGES OF CONVENTIONAL AND PERIPHERAL DISC BRAKE SYSTEM

Brake Force

In the conventional disc brake system Disc is very small as compared to the peripheral disc brake setup. Assume that the frictional force needed to stop the vehicle is same in both the cases. Let, F_{BC} is breaking force required for conventional disc brake system, F_{BP} is breaking force required for peripheral disc brake system, r_1 is radius of conventional disc and r_2 is radius of peripheral disc.

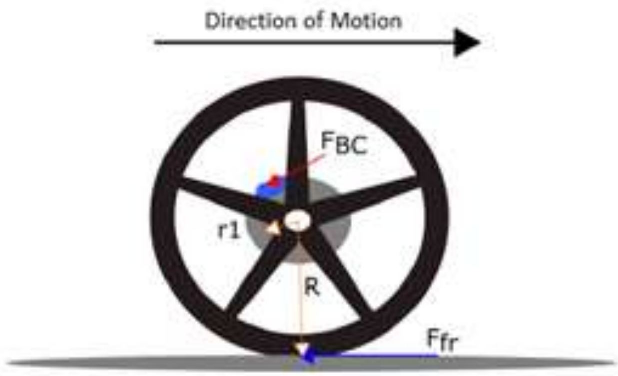

Fig. 1 Braking force on Conventional Disc

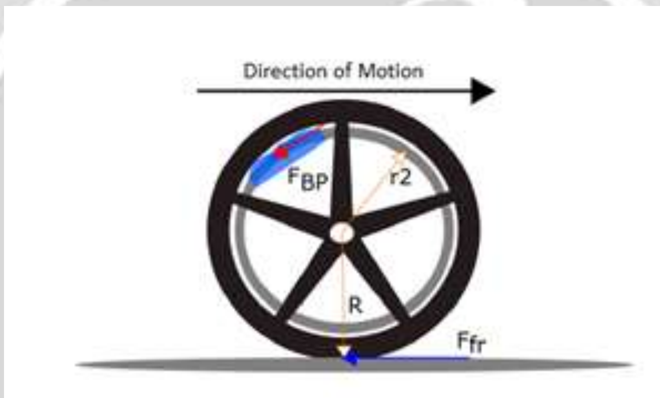

Fig. 2 Braking force on Peripheral Disc

As frictional force is same,
So, $F_{BC} \times r_1 = F_{BP} \times r_2$
And as, $r_2 > r_1$ so $F_{BP} < F_{BC}$
From the analysis, braking force required for the conventional disc is greater than the peripheral disc to stop the vehicle. From this we can say that peripheral disc is more beneficial than the conventional disc brake. For safety purpose vehicle can be stop immediately, with less braking force.

Brake force flow for spoke design

When the brakes were applied, the braking force gets transferred from brake disc to tires and road surface through the spokes.

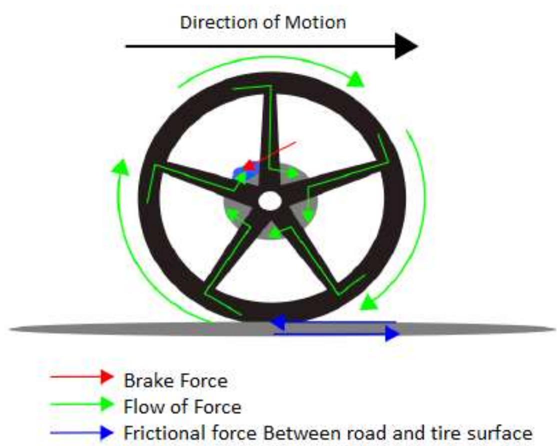

Fig. 3 Force Flow of Conventional Disc Brake

Theoretical analysis of load distribution path is carried out with the help of simple mechanics for the spokes design.

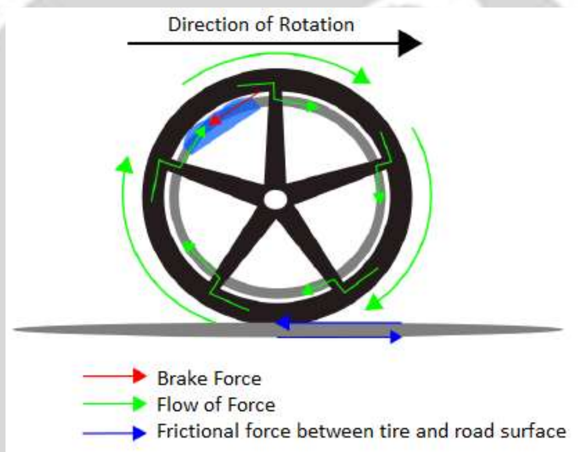

Fig. 4 Force Flow of Peripheral Disc Brake

In peripheral disc brakes, disc is attached very close to the rim, so directly the braking force is transferred to the tire without transferring the force through the spokes where as braking force gets transferred through the spokes in the conventional disc brakes. So, weight of the wheel can be optimized in the spokes where we are using the peripheral disc setup. Also in brake force flow there is no need to transfer brake force through the spokes. In peripheral disc brake disc is attached directly on the rim of tire, so after applying brake force complete periphery of the rim of tire gets brake force at a time. so vehicle can stop within a second.

7. DESIGN OF CONVENTIONAL AND PERIPHERAL DISC

Material Selection:

For the Brake Disc following material is selected from the catalogue.

Designation	Ultimate Tensile Strength, N/mm2	Yield Strength N/mm2
EN8	520	360

For the brake standard Asbestos pads are used due to good characteristic of heat absorption from the disc and dissipation and average stopping power.

Design of Brakes:

According to availability of the rim diameter of the wheel, peripheral disc is manufactured and conventional disc for the wheel is selected for the experimentation purpose.
Maximum Brake Power Absorbed is 33 Watt
Area in contact with brake pad = 225 mm2
Heat Flux = 33/225 = 0.146 W/mm2

Conventional Disc brake Mass Property Values:

Volume	12570.47	mm^3
Area	21090.95	mm^2
Mass	0.0984	Kg
Weight	0.965	N
Radius of Gyration	59.395	mm

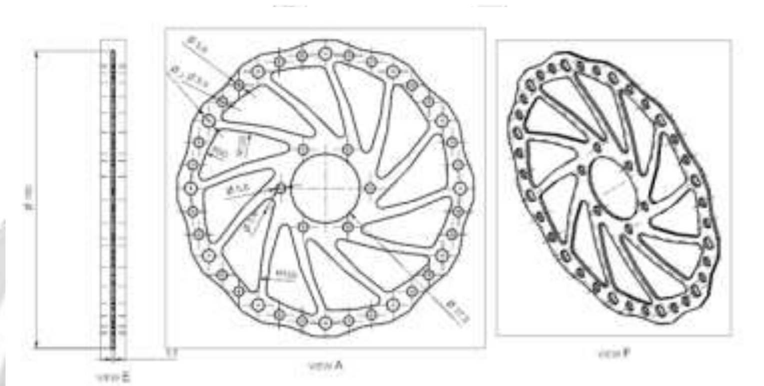

Fig. 5 Drafting of Conventional Brake Disc

Mass Property Values for Peripheral Disc Brake

Volume	74082.289	mm^3
Area	64489.0431	mm^2
Mass	0.580	Kg
Weight	5.688	N
Radius of Gyration	117.50	mm

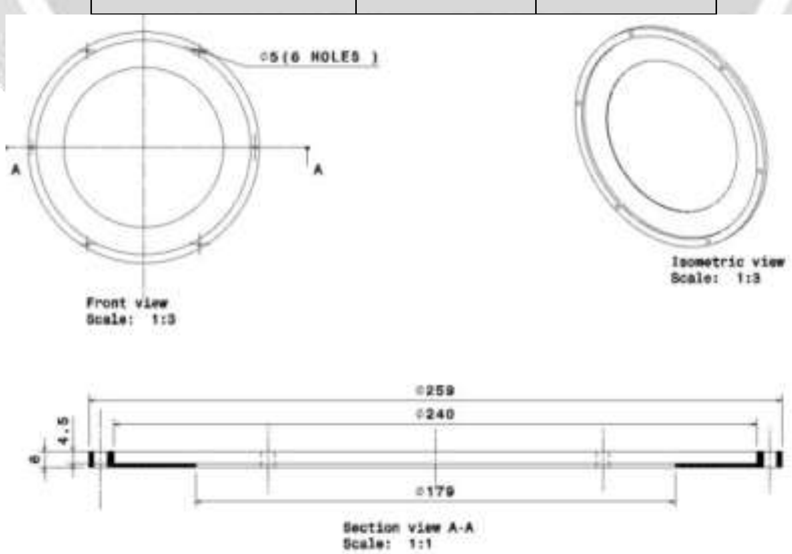

Fig. 6 Drafting of Peripheral Brake Disc

8. COMPUTATIONAL ANALYSIS

To carry out the experimentation of conventional and peripheral disc brake system on the wheel assembly, initially the computational analysis is carried out to check the safety of the designed discs under the structural and thermal conditions. Computational analysis is carried out on the conventional and peripheral disc brake system and following boundary conditions are used for the analysis.

Braking Torque on the disc= 252 N.mm
Heat Flux = 0.146 W/mm^2
For Conventional Disc Brake:
Mesh:

Nodes	98544
Elements	15780
Average Element Quality	0.8964
Element Type	Hexa
Element Size	1 mm

Fig. 7 Mesh of Conventional Brake Disc

Boundary Conditions:
Fixed support: At the bolted faces
Braking torque: 252 N. mm

Fig. 8 Boundary Conditions for Conventional Brake Disc

Fig. 9 Equivalent Von Misses Stress in Conventional Brake Disc

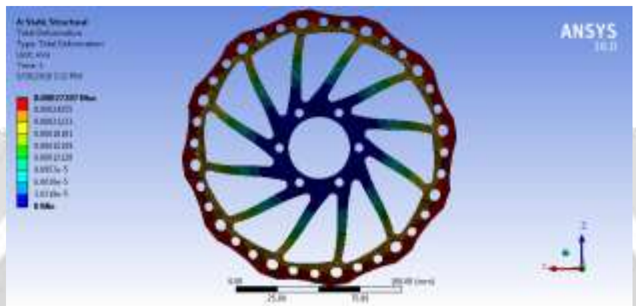

Fig. 10 Total Deformation of Conventional Brake Disc

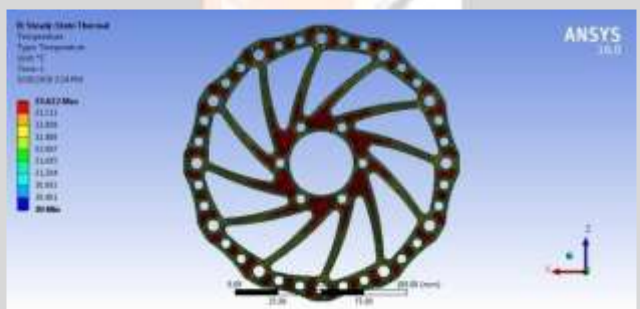

Fig. 11 Temperature induced in Conventional Brake Disc

Mesh Sensitivity Analysis:

Results of total deformation are evaluated at different mesh sizes to check the mesh sensitivity analysis.

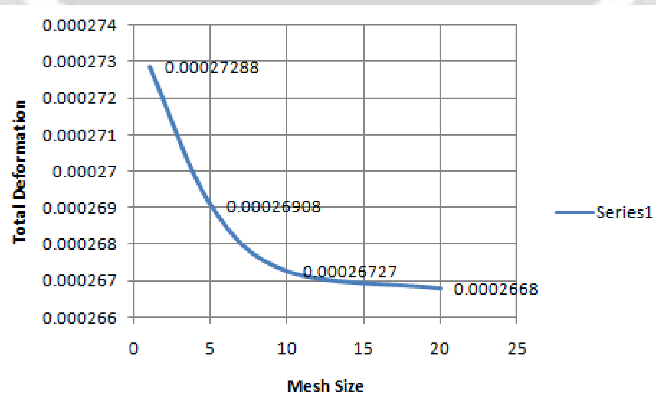

Fig. 12 Mesh Sensitivity Analysis of CDB

From the analysis it is observed that when the mesh size is 1 mm that time the results obtained are satisfying the design criterion that is we are getting maximum deformation which is useful for design criterion.

For Peripheral Disc Brake:

Mesh:

Nodes	73051
Elements	11861
Average Element Quality	0.8720
Element Type	Hexa
Element Size	2 mm

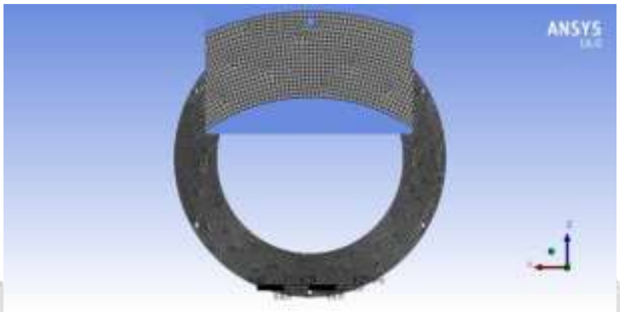

Fig. 13 Mesh for Peripheral Brake Disc

Boundary Conditions:
Fixed support: At the bolted faces
Braking torque: 252 N. mm

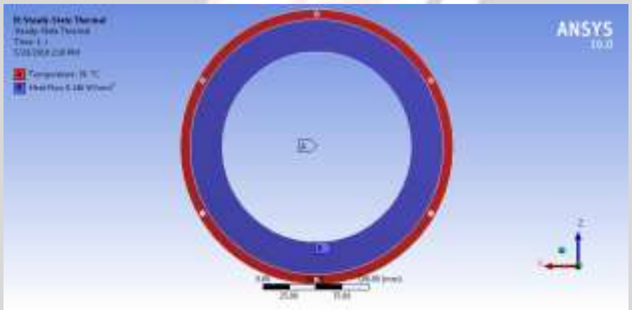

Fig. 14 Boundary Conditions of Peripheral Brake Disc

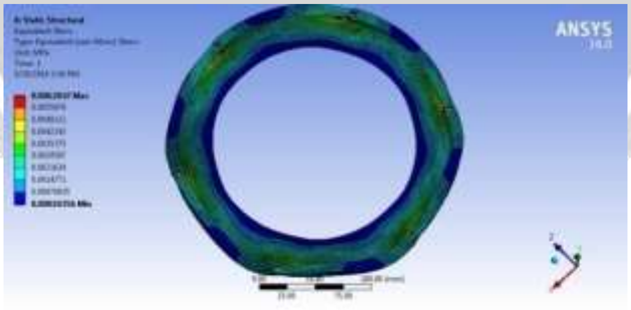

Fig.15 Equivalent Von Misses Stress in Peripheral Brake Disc

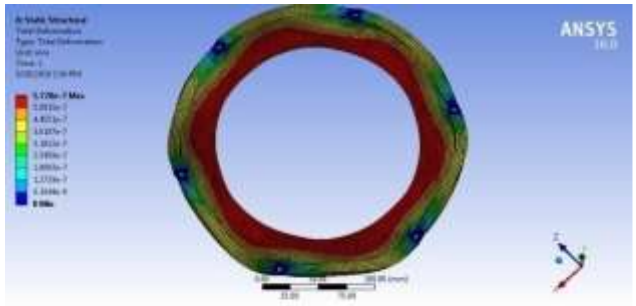

Fig.16 Total Deformation of Peripheral Brake Disc

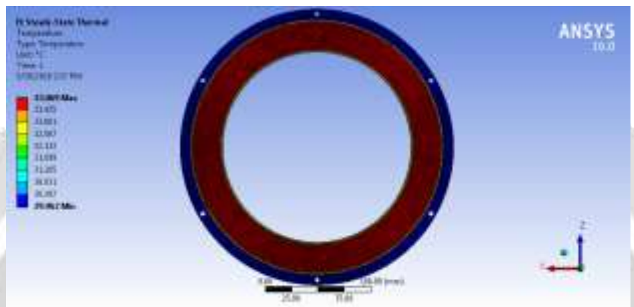

Fig.17 Temperature induced in Peripheral Brake Disc

Mesh Sensitivity Analysis:
Results of total deformation are evaluated at different mesh sizes to check the mesh sensitivity analysis.

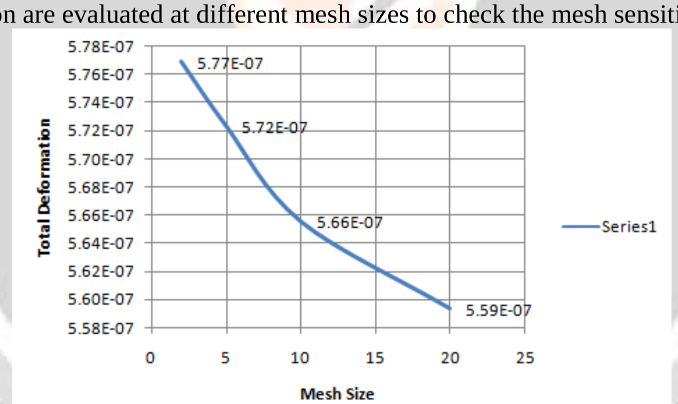

Fig. 18 Mesh Sensitivity Analysis of PDB

From the analysis it is observed that when the mesh size is 2 mm that time the results obtained are satisfying the design criterion that is we are getting maximum deformation which is useful for design criterion.
Summary of the Computational Results:

Particulars	Conventional Brake Disc	Perimeter Brake Disc
Total Deformation	0.0002728	5.72E-07
Von Misses Stress	0.46136	0.00628
Temperature in ºC	33.612	33.869

9. EXPERIMENTAL ANALYSIS

Fig. 19 shows the setup of test rig for experimental validation of Conventional Brake and Perimeter Brake. It consists of AC motor of 50 Watts (50 Hz, 0.35 amps) which rotates the wheel by transmitting power through the open belt. Conventional brake disc and perimeter brake disc are fixed on input shaft which is supported by single deep groove ball bearing. Adjustable brake caliper is attached to the disc to apply the braking force. Force can be applied by adding the dead weight at the lever. Rotations of the wheel are measured with the help of non contact type Tachometer.

Fig. 19 Experimental Setup

Procedure for Experimentation:

- ✓ Start motor
- ✓ Maintain speed of shaft @ 1300 rpm (Measured with the help of non contact type tachometer)
- ✓ Note no load speed
- ✓ Add 0.5 kg dead weight to the pan.
- ✓ Note speed @ 0.5 kg load.
- ✓ Take the readings at different loads such as 1kg, 1.5 kg, 2 kg and 2.5 kg.
- ✓ Compare the results of the conventional and perimeter brake disc.

Results of Experimental Analysis:

$$\% \text{ Slip} = \frac{TheoreticalSpeed - ActualSpeed}{TheoreticalSpeed} \times 100$$

Conventional Disc Brake Setup Results:

Sr. No.	Load	Actual Speed	Theoretical Speed	% Slip	Brake Power Absorbed
1	0.5	826	830	0.48	31.82
2	1	406	416	2.46	31.29
3	1.5	265	275	3.77	30.63
4	2	198	207	4.55	30.51
5	2.5	159	167	5.03	30.63

Peripheral Disc Brake Setup Results:

Sr. No	Load	Actual Speed	Theoretical Speed	% Slip	Brake Power Absorbed
1	0.5	562	564	0.36	32.26
2	1	278	281	1.06	32.30
3	1.5	186	189	1.58	31.70
4	2	135	139	2.87	32.43
5	2.5	115	119	3.36	33.48

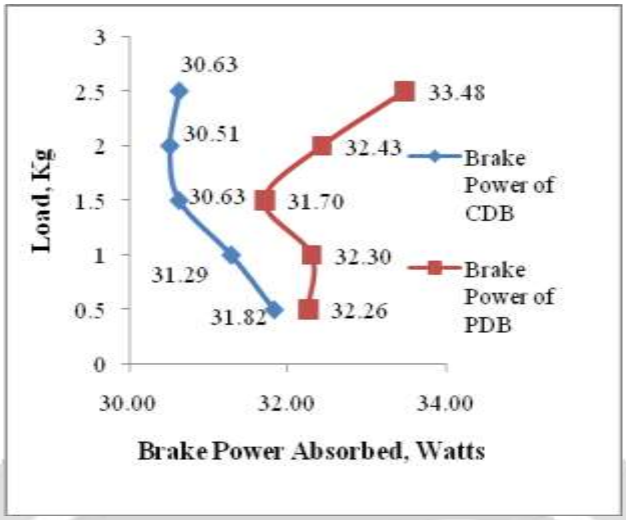

Fig. 20 Comparison Plot of Absorbed Brake Power by Conventional Disc Brake VS Peripheral Disc Brake

Figure 20 shows the graphs of load VS brake power absorbed by conventional disc brake and the peripheral disc brake system. From the graph it is seen that the brake power absorbed by the peripheral disc brake system is more than the conventional disc brake system means peripheral disc can absorb more power from rotating disc and will try to stop the disc within a shorter time.

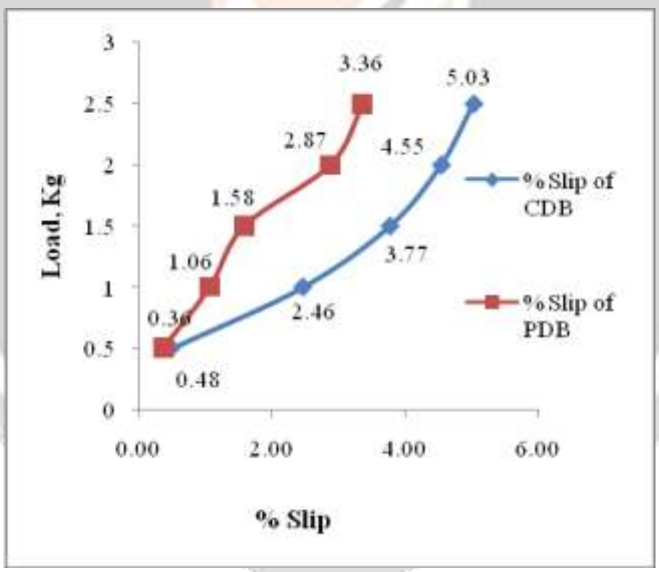

Fig. 21 Comparison Plot of % Slip of Conventional Disc Brake VS Peripheral Disc Brake

Fig 21 shows the graphs of load verses % slip of conventional disc brake and peripheral disc brake by using formula of % slip. % slip is calculated and then plotted the graph . When we compare the % slip of conventional disc brake and peripheral disc brake % slip of peripheral disc brake is less than conventional disc brake.

10. CONCLUSION

1. From the theoretical analysis it is found that the brake force required to stop or to minimize the speed of the wheel is less in case of the peripheral disc as compared to the conventional disc brake.
2. From the theoretical analysis it is concluded that the brake force does not passes through the wheel through spokes in case of the peripheral disc brake system. Design of the spokes can be optimized.

3. From the computational analysis it is found that the total deformation of the conventional brake disc is 0.0002728 mm while its 5.72E-07 mm only for the perimeter brake disc.
4. For conventional brake disc VON MISSES stresses developed maximum value is 0.46136 MPa where as it is drastically less as 0.00628MPa for the perimeter disc brake.
5. Thermal analysis of the brake disc says as conventional disc is optimized one so temperature induced in the disc after braking is 33.612 ºC whereas due to more surface area exposed to the air and large size of the disc the temperature induced in the non optimized peripheral disc was around 33.8ºC.
6. Percentage slip in case of conventional disk brake system was found to be 5.03 % which is comparably greater than that of the perimeter brake which is 3.36 %.
7. Overall performance of the peripheral disc brake was found to be much better as compared to the conventional disc brake in term of load required to stop the vehicle, load distribution along the spokes, deformations and stresses developed, braking time and % slip.

11. FUTURE WORK

It is required to do the Weight and Topology optimization of the peripheral disc brake so that weight of the disc will be as much less as possible. Vibration analysis of the system is required to carry out so as to find the different mode of vibration, frequency of vibrations to minimize the noise produced during the braking.

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