Design optimization of passenger car front brake disc for improvement in thermal behavior, weight & Cost reduction.

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Abstract: -This work is presented with "Design modification & optimization in stress, improvement in thermal behavior, and weight & cost reduction of Disc brake rotor" which studies about on disc brake rotor by modeling & analysis of two different shapes brake disc. Two Different disc brake rotors with same outer diameter & inner mounting position of holes on wheel hub as like four wheeler. Analysis done on real model of disc brake rotor of four wheeler and disc brake Rotor of different shapes of slots of different vehicle's in one Disc brake rotor. Therefore, it gives optimize stress, deformation, weight & cost reduction of the modified disc brake rotor & also good heat dissipation. Hopefully this project will help everyone to understand experimental verification of disc brake rotor and how disc brake works more efficiently, which can help to reduce the accident that may happen in each day.

In automotive engineering, the safety aspect has been considered as a number one priority in development of a new vehicle. Each single system has been studied and developed in order to meet safety requirements. Instead of having air bags, good suspension systems, good handling and safe cornering, one of the most critical systems in a vehicle is the brake system. The objective of this work is to investigate and analyze the temperature distribution of rotor disc during braking operation using ANSYS Multiphasic.

In the present work, different ventilated disc brake rotor configurations were analyzed to enhance the heat transfer rate and obtain the uniform temperature distribution in the rotor. CFD code used in this work was validated at using experimental results obtained by conducting experiments on a test rig. The experimental analysis was performed to calculate the mass flow rate and heat dissipation through the rotor. Further, different types of rotor configurations viz. straight radial vane (SRV), pillar type vanes, were considered for the analysis.

Index Terms:-1 Introduction, 2.Case study, 3.Methode of study, 4.experimental results 5. Conclusion, 6. References.

Keywords: *Two different brake disc (existing and modified), optimize slots, heat dissipation, CAE and experimental verification, cost & weight reduction.*

I. INTRODUCTION

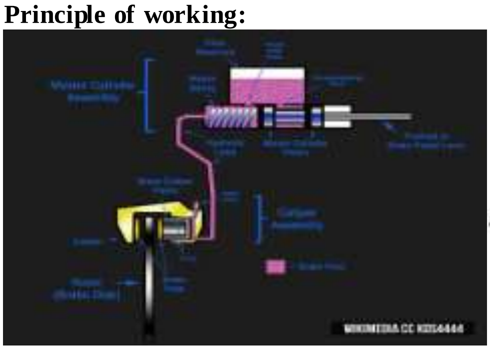
Importance

While braking, most of the kinetic energy is converted into thermal energy and thus, it increases the disc temperature. This project consists of thermal stress analysis on four wheeler brake disc rotor for steady state and transient condition. The heat dissipated along the brake disc surface during the periodic braking via conduction, convection and radiation. In order to get the stable and accurate result of element size, time step selection is very important and all of these aspects are discussed in this paper. The findings of this research provide a useful design tool to improve the brake performance of disc brake system.

Need

A problem in Disc Brake occurs because of uneven stress & heat dissipation during braking of four wheeler as follows:-Scarring, Cracking, Rusting, Poor stopping, noise, Vibration, Pulling, Grabbing, Dragging, Pulsation etc.

Principle of working:



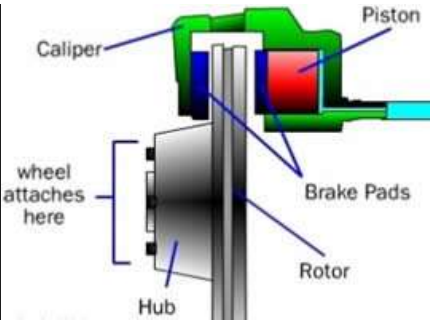


Fig.1 Principle of working of disc brakeFig.2 single-piston floating caliper disc brakes

When hydraulic pressure is applied to the caliper piston, it forces the inside pad to contact the disc. As the pressure increases, the caliper moves to the right and cause the outside pad to contact the disc. Braking force is generated by friction between the disc pads as they are squeezed against the disc rotor. Since disc brakes do not use friction between the lining and rotor to increase braking power as drum brakes do, they are less likely to cause a pull. The friction surface is constantly exposed to the air, ensuring good heat dissipation, minimizing brake fade. It also allows for self-cleaning as dust and water is thrown off, reducing friction difference.

Disc rotor:-

Generally, the disc rotor is made of gray cast iron, and is either solid or ventilated. The ventilated type disc rotor consists of a wider disc with cooling fins cast through the middle to ensure good cooling. Proper cooling prevents fading and ensures longer pad life. Some ventilated rotors have spiral fins which create more air flow and better cooling. Spiral finned rotors are directional and mounted on a specific side of the vehicle. Solid type disc rotor is found on the rear of four-wheel disc brake system and on the front of earlier model vehicles.

A third style rotor can be either the ventilated or solid type which incorporates a brake drum for an internal parking brake assembly.

II. Case study:-

Problem Statement

Existing brake disc performance improvement is under consideration. The analysis focuses on two discs for airflow and thermal consideration. It is required to determine the temperature and heat transfer coefficient. Analysis is done for Design of old disc (pillar post)and proposed disc (straight vents). Heat input is give in terms of heat flux (W/m2), vehicle speed (velocity m/s) and different disc speed (rpm) against single brake cycle time.

Design parameters of Existing and New Discs:

Parameter	Existing Brake Disc	Proposed Brake Disc
Part No	Pillar type.	Straight vent type
Weight	9.3 kg	8.38 kg
Thermal Mass	5.9 kg	6.36 kg
Gap and air flow passage Between Knuckle and Disc	Narrow (refer below image)	Improved (refer below image)

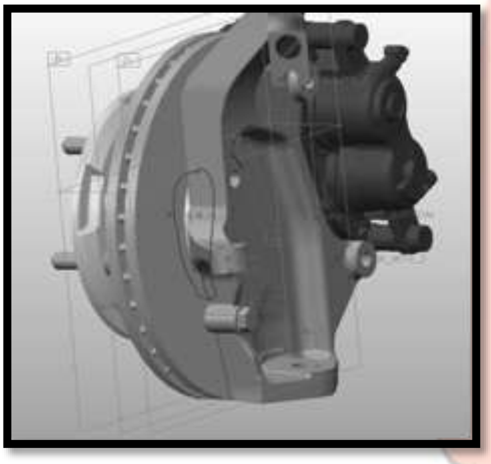


Fig: 3existing pillar type without cut out

figs: 4 Propose straight vent type with cutout

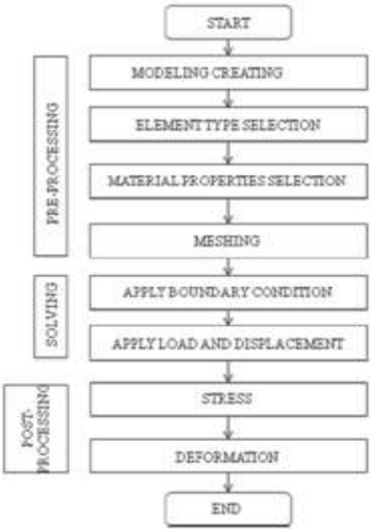
Earlier CAE recommendations were provided for modifying stub axle to improve ventilation. Due to tooling constrain stub axle modification was not possible. Current straight bents design is improved at air suction zone to increase airflow. This design change is considered for analysis for one braking cycle.

III. Method of study:-

Used Pro-e software.pro-e is mechanical design software.Pro-e users access the highest productivity for specific advanced processes with focused solutions.

- Sketcher
- Part design
- Assembly design
- Wireframe and surface design
- Drafting
- Analysis of disc brake in pro-e
- Meshing

Structural and thermal analysis by ANSYS software



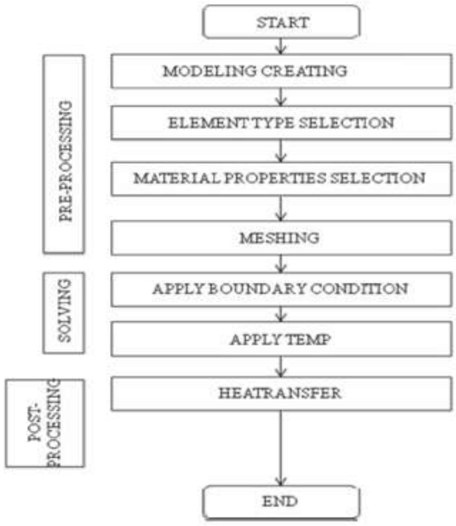


Fig. 5 Flowchart of Structural Analysis. Fig.6 Flowchart of Thermal Analysis.

Design of disc brake

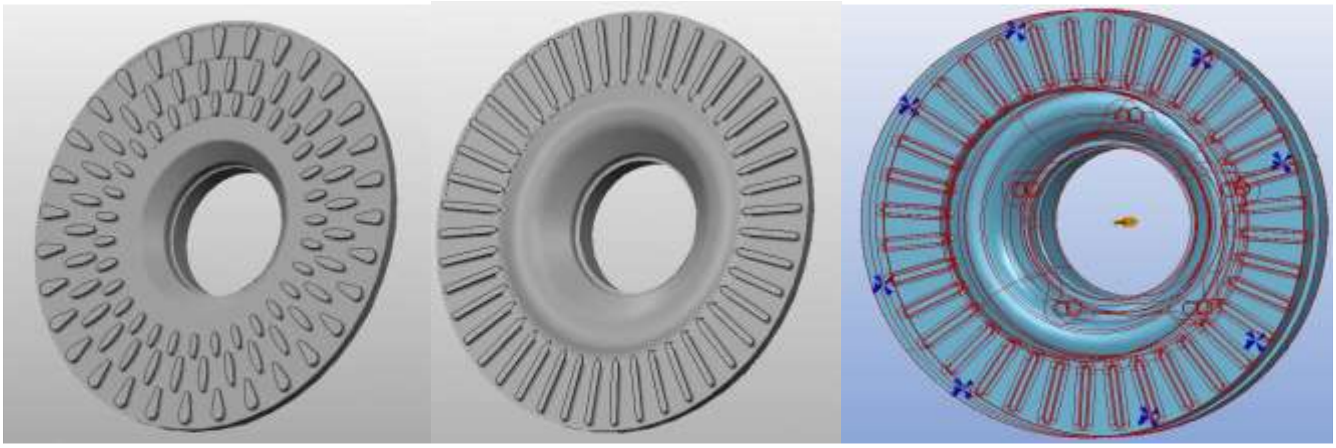
Design of Disc Brake for Find Suitable Dimensions:-
In this project study standard of four wheeler Automobile Factor;
Rotor disc dimension = Dia.302 mm & 26mm Thk.
(Rotor disc material = Gray cast iron)
Pad brake area = 12700mm^2 (1.27×10^{-2} m^2)
Pad brake material = Asbestos,
Threshold pressure (bar) =0.7
Thermal mass (kg) =6.4
Coefficient of friction (wet) =0.07-0.013
Coefficient of friction (dry) = 0.3-0.5

Calculation for heat flux & stopping distance:-

*tire and road friction coefficient =0.8 as per IS standard.
g=9.8m/s
Deceleration (a) =μ x g =0.8 x 9.8 =7.8m/s^2
Stopping distance(X) =?
v=u+ at
S=u t + (1/2) at^2
Gross vehicle weight (m) =2806 kg.
Velocity or max. Speed (U max) =180 km/h. = (180x1000)/3600=50 m/s.
Br. split (F/R) =70:30
Front contribution =70% of total.
Kinetic energy = (mv^2) / 2 = (2806x50^2) / 2 =3507500 Nm.
K.E $_{front}$ =0.7x3507500=2455250 Nm
K.E $_{front\ per\ wheel}$ =1227625 Nm.
V $_{max}$ =50m/s.
v=u + at
0=50+ (-7.81) X t
t= 6.34 sec.
V^2 = u^2+2aS
(V^2- U^2)/2a=S
S=0-(50X50)/ (2X7.8)
S=160m
W.D=Ft x X
Ft x X = (1/2) mv^2
(08x2806x9.81) x X= (1/2) (2806) (50x50)
X=160m.
P= (K.E $_{front\ per\ wheel}$)/time
P=1227625/6.34
=193631 w =193.6 Kw.
Total pad area (A) =127 cm$^{2.}$
= (127)/10^4 m^2
Heat Flux= heat generated/sec/area
= (193631/127) x10^4
=15246.6kw/ m^2

Cad modeling:-

Existing pillar vane brake discNew straight vane typeDisc modeling



Structural analysis in pro-e

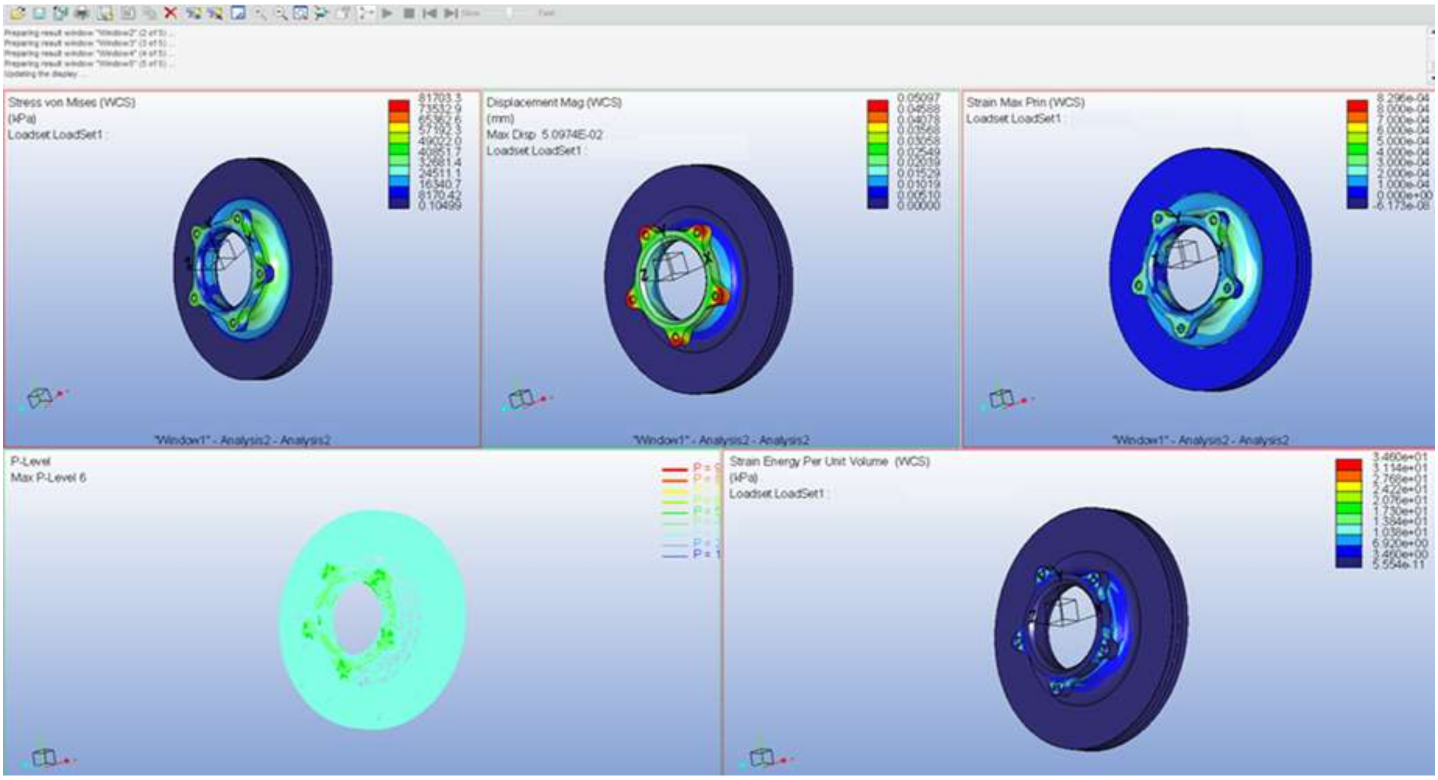


Fig: 7

Thermal analysis:-

Assumptions-

1) Time variation: transient state analysis.

2) MRF model is used for rotating assembly with specified RPM (fig: &) where brake pads & disc got heated during the brake application respective to the braking cycle as below:

Air properties are taken @450dc standard temperature.

Convection and conduction mode of heat transfer are considered.

Boundary conditions-

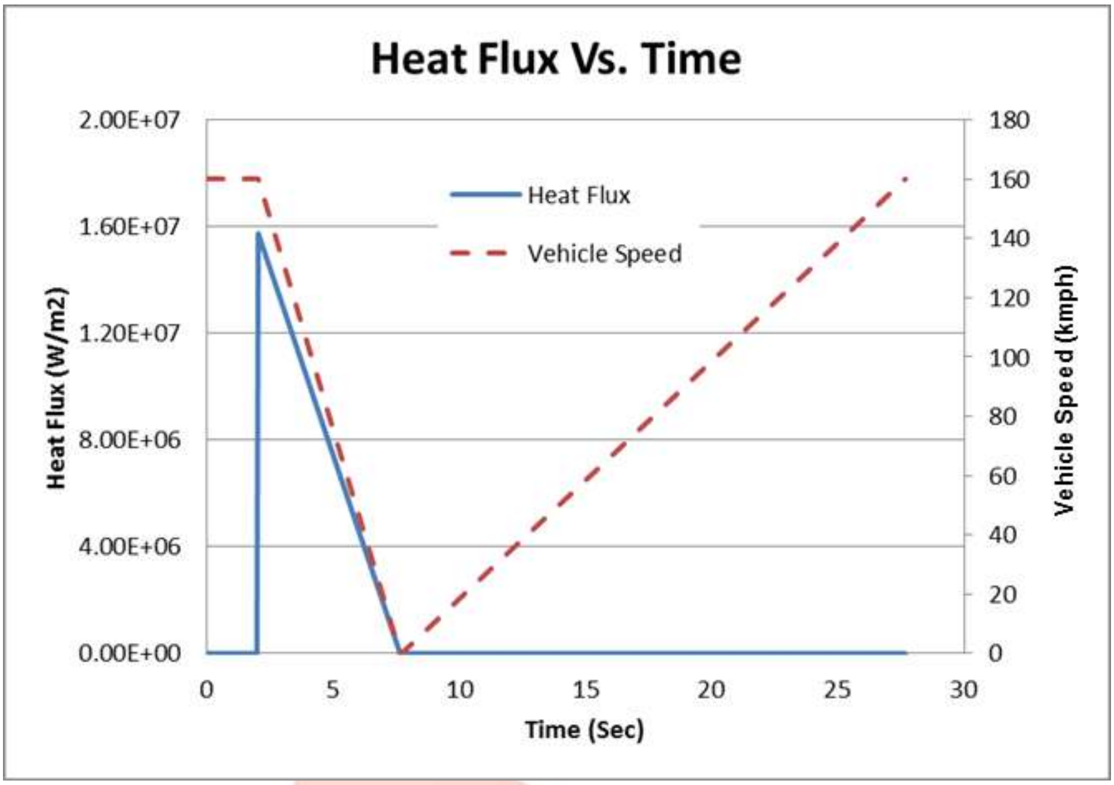

Heat Flux Vs. Time
2.00E+07
1.60E+07
1.20E+07
8.00E+06
4.00E+06
0.00E+00
Heat Flux (W/m2)
180
160
140
120
100
80
60
40
20
0
Vehicle Speed (kmph)
Heat Flux
Vehicle Speed
0
5
10
15
20
25
30
Time (Sec)

Fig:-8

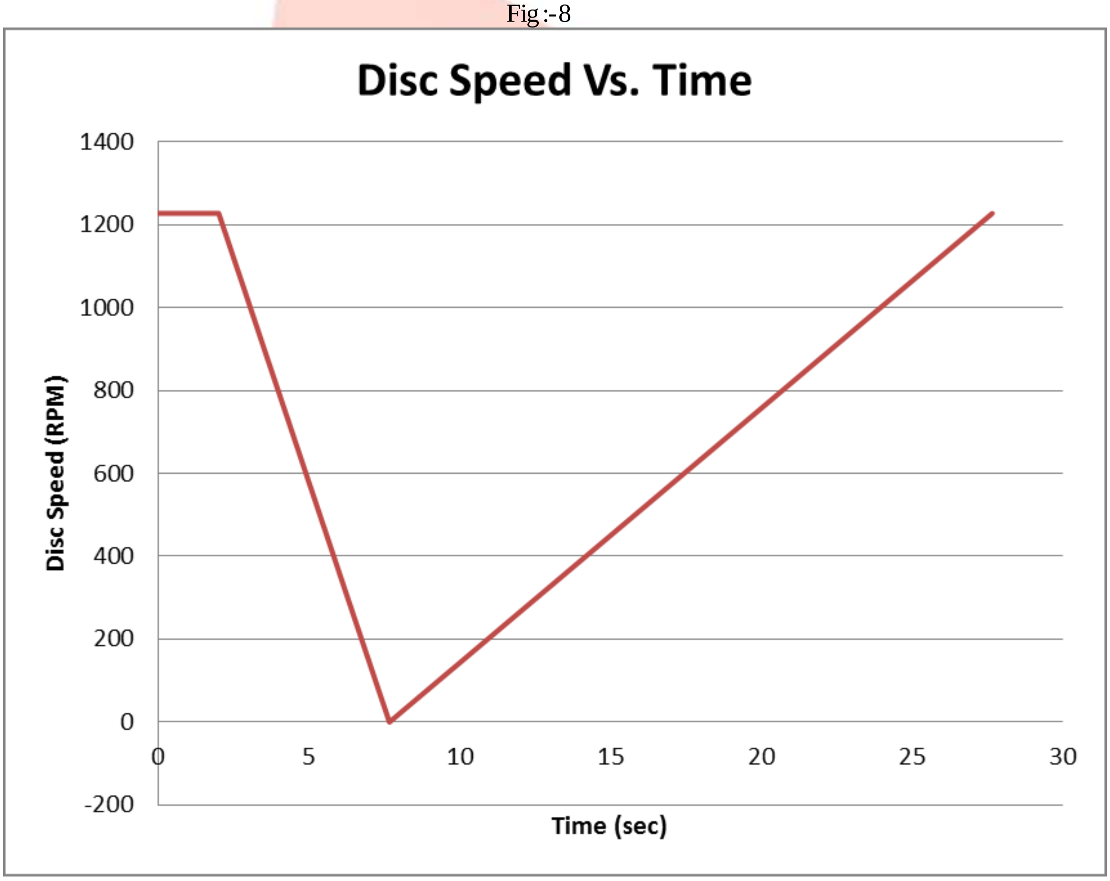

Disc Speed Vs. Time
1400
1200
1000
800
600
400
200
0
-200
Disc Speed (RPM)
0
5
10
15
20
25
30
Time (sec)

Fig:-9

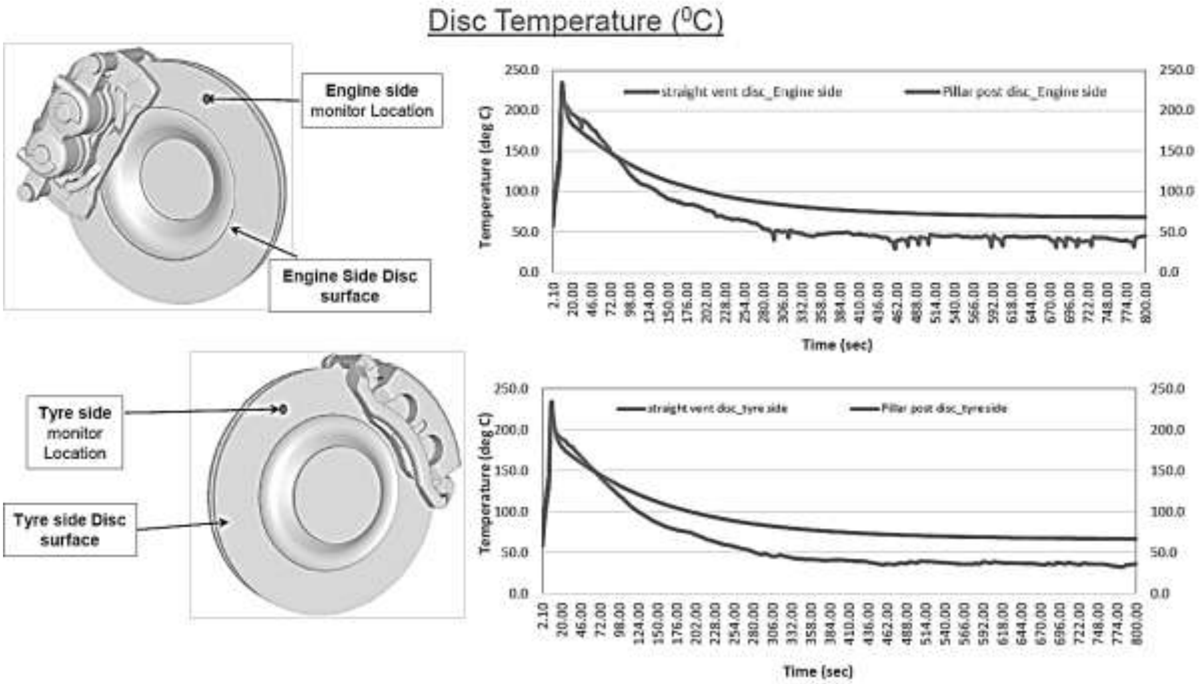


Fig:-10 Straight vent disc shows better cool down than pillar post disc.

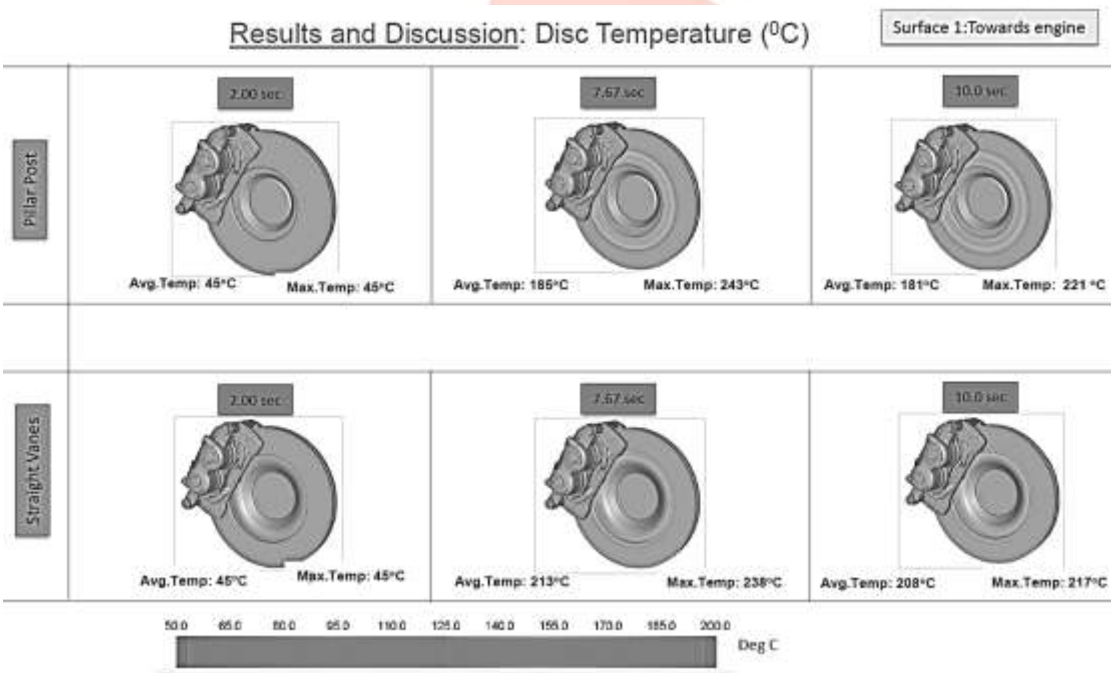


Fig:-11

Conclusion:

1) At the end of braking (7.67sec) avg. temperature on disc face (engine and tyre side)of vent disc is slightly higher than pillar post vent disc.
2)Max disc temperature is almost similar.
3) Average heat transfer coefficient of vent disc is seen higher than pillar post disc.
4) Disc modification at air entry is straight vent has resulted in airflow improvement.

Recommendation:

1)To further improve airflow in vented disc, stub axle modification is required.
2)Curve vents will further improve cooling of disc.

IV.Experimentation:-

Fig:-12Fig:-13 Temperature gun

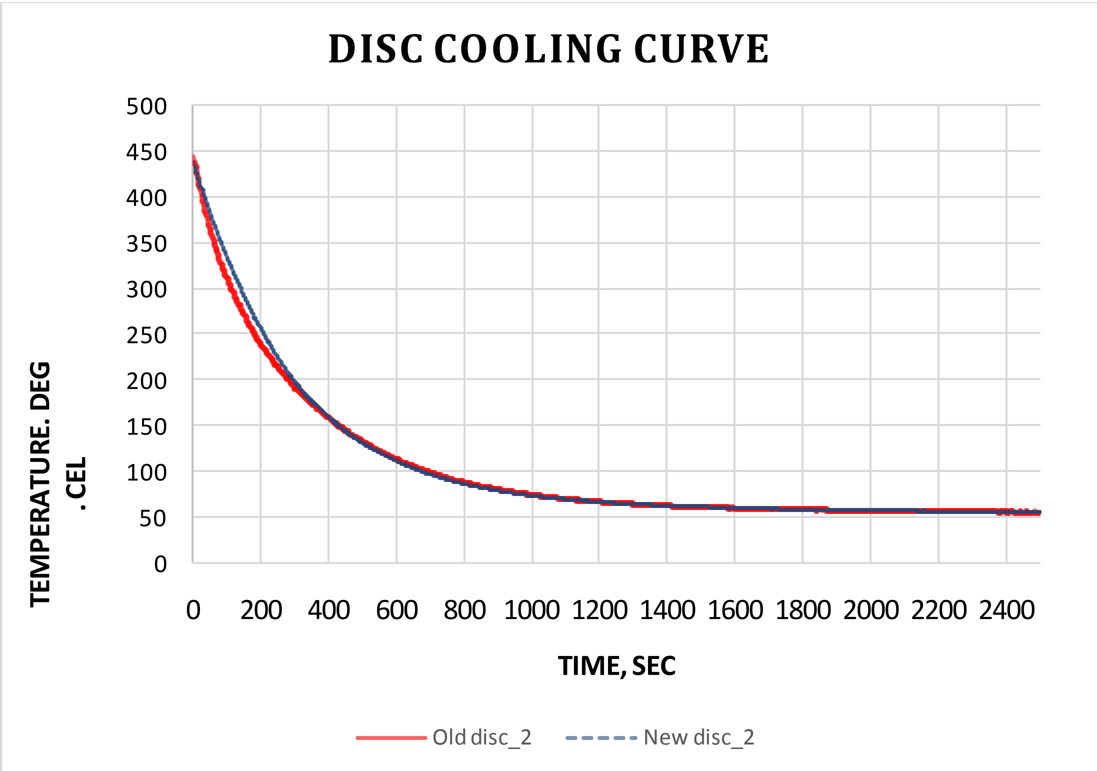


Fig:-14

V.CONCLUSION:-

In automobile passanger cars brake disc vans should be in straight or curved and brake disc modifications are easly becose knkle tooling changes are very costly than barke disc .

To achieved cost and weight reduction in brake disc.

Parameter	**Existing Brake Disc**	**Proposed Brake Disc**	**Achievement**	**Cost**
Part	Pillar type	Straight vent type		
Weight	9.3 kg	8.38 kg	1 kg weight reduction	65 Rs per disc Cost reduction.
Thermal Mass	5.9 kg	6.36 kg	0.46 kg increase	
Gap and air flow passage Between Knuckle and Disc	Narrow (refer below image)	Improved (refer below image)	More gap for air circulation	

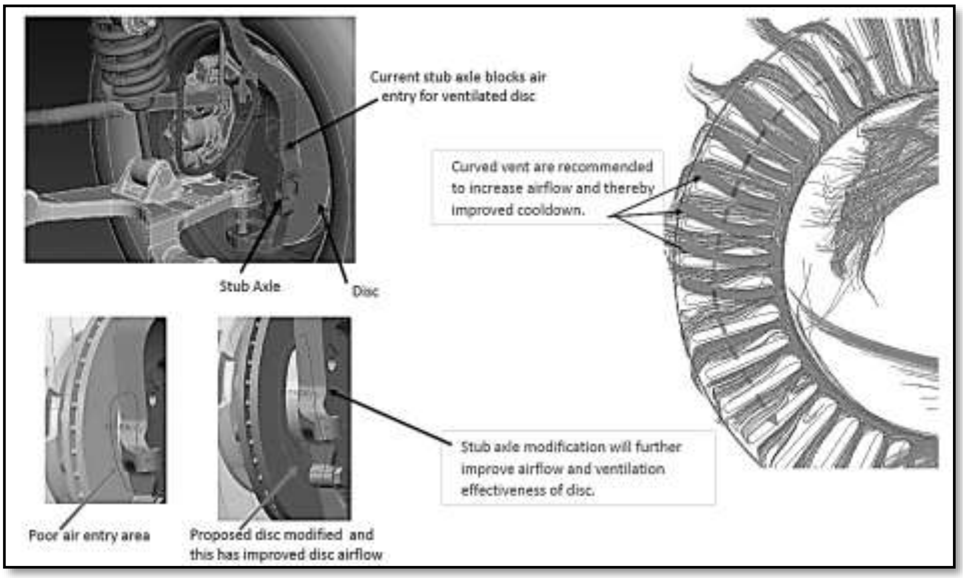


Fig:-15

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