Design and Thermal Analysis of Disc Brake In Automobiles

Mallesh Jakanur[1], Rohan I[2], Manjunath V B[3], Sangamesh Herakal[4]
[1, 2, 3, 4] Assistant Professor, Dept of Mechanical Engineering
[1, 2, 3, 4] Holy Mary Institute of Technology and Science, Hyderabad

Abstract- *Braking system is a technique which converts the kinetic energy of an automobile into mechanical energy, which must dissolute in the form of heat A brake disc usually made of cast iron or ceramic composites, is attached to the wheel. Rubbing material in the form of brake pads is enforced mechanically, hydraulically, pneumatically or electromagnetically in opposition to both sides of the disc and prevents the wheel to rotate. This paper is presented with "Design and Thermal analysis of disc brake for minimizing temperature" which studies about on disc brake rotor by analysis of different shapes of slot of different vehicles Disc brake rotor. Therefore, we can optimize number of shapes of slot to estimate the good thermal conductivity of the disc brake rotor. In this paper, Thermal analysis done on real model of disc brake rotor of bike and Thermal analysis of disc brake rotor. Different shapes of slot are because of to reduce the weight of disc rotor and for good thermal conductivity. Modeling was done using CATIA V5R21 software and Static and Transient Thermal Analysis was done using ANSYS 15 software.*

Keywords- Braking system, Thermal Analysis, Disc Brake.

I. INTRODUCTION

Brakes are mechanical or on occasion electrical devices or portion that help to decelerate the vehicle and over the long haul stop the vehicle in a particular time and certain partition called the stopping detachment or the braking division. The auto brake is basically a mechanical contraption which controls development, directing or stopping a moving article, here, the vehicle, and thusly keeping its development. Brakes are a champion among the most gigantic prosperity systems in any auto. Working of brakes relies upon the protection of essentialness. Most commonly used brakes are frictional brakes, where the grinding made between two articles convert the dynamic essentialness of the moving vehicle into warm imperativeness. In this project we design rotor of disc brake.

For execution of braking operation, the brakes pad and disc absorb the kinetic energy from wheel. The energy absorbed by brake is generating heat. This heat is passing in to the atmosphere and stops the vehicle, so the braking system should have the following ability;

1. The brake disc having ability to transfer heat to atmosphere and maintain constant temperature to improve performance of disc.
2. Anti-wear property of the brakes must be good.
3. The driver must have proper control on the vehicle during brake applied and the vehicle should not skid.
4. The brakes must be having enough power to stop the vehicle with in a minimum distance in case emergency.

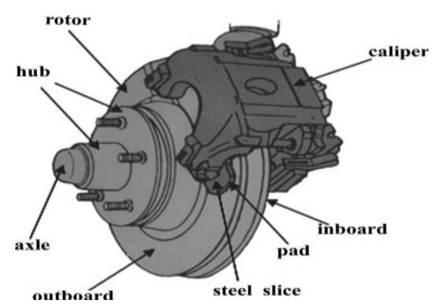

Fig.1. Disc Brake

1.1 CLASSIFICATION OF BRAKES

The classification of mechanical braking system in 2 subgroups according to the direction of acting forces are,

Axial brake: In this brake, the force acting on the braking system is only in the axial direction to the brake. For example, Disc brake is acting in axial direction.

Radial brake: In this brake, the force acting on the braking system is in perpendicular to axial direction. The radial brakes subdivided into internal and external brake.

II. LITERATURE REVIEW

1.N. Balasubramanyam, Smt. G. Prasanthi In this project, three-dimensional modeling and meshing Structural & thermal analysis using the simulation program ANSYS were successfully implemented. This has allowed for greater flexibility and accuracy in the results achieved. They were taken 3 different materials of disc brake using constant hydraulic pressure 1 Mpa at time of running condition & analysis. On the basis of various results gathered from the analysis, it is decided that grey Cast Iron is the suitable material for disc brake.

2. Subhasis Sarkar, Pravin P. Rathod In automobile brake system ventilated disc brake is the a rt of technology. This research paper reviews work of previous investigators on transient thermal analysis on the design rotor and ventilated rotor disc is to compare and evaluate their performance. The aim of this research paper review work is to study various research done in past to improve heat transfer rate of ventilated disc brake by changing material and vane geometry. If vane is angled and of alternate length other than straight radial vane. Contact time between air flow and vanes (time between air inlet and outlet flow through vanes) is also important factor in heat transfer from Disc rotor. There is also scope of research in improvement of heat transfer of rotor by increasing the contact time between vanes and air flow by design modification of vanes in such way that fulfils the requirement.

3. Harshal Nikam et.al All conveyed that moving vehicle have dynamic importance whose respect relies on the mass and speed of the vehicle. Consequently, it is the limit of the moving back framework to change over the dynamic vitality controlled by the vehicle in warm importance by methodologies for contact. This shine vitality must be somewhat or completely dispersed when the driver applies brakes to log stick the vehicle or get it to end instance of crisis. In masterminding of braking circuit of vehicle the fundamental criteria to be considered is Braking Torque is done to decide the Deflection, Normal Stress, Vonmises pressure.

4. Atul Sharma and M. L. Aggarwal This research paper explains the design and finite element analysis (FEA)model of brake disc by which deflections in X, Y, Z direction and Von mises stress can be calculated by applying boundary conditions. The FEA outcomes are correlated with experimental data. The model is safe under the practical loading condition and our factor of safety is 20.34.

5. Ameer Fareed Basha Shaik, Ch. Lakshmi Srinivas The paper presented here is a study of model of a disc brake of Honda Civic. In this paper Structural & Thermal analysis was done in the brake disc. After changing the design of disc brake analysis was done. The material used as Cast Iron. Actual disc brake has no holes, changing the design of the disc brake by giving certain holes for more heat dissipation. Modelling was done in Catia and Analysis is done in ANSYS. Study the amount of deformation due to pressure loading and tangential Force. The modular brake was then analysed using a nodal temperature of 300ºF. These results were used to study the increase in deformation in the caliper at high temperatures. The displacement increased as compared with the previous case. Since race cars brakes always operate at high temperature the thermal deformation/displacement results are important.

6. M. Nouby and K. Srinivasan et.al Circle brake screech clamor is an exceptionally confounded wonder, which vehicle makers have faced for a considerable length of time because of steady client protests and high guarantee costs. As of late, the limited component technique (FEM) has turned into the favored strategy because of high equipment expenses of trial strategies. In this examination, a rearranged model for the plate brake is introduced utilizing the Standard limited component programming. The investigation procedure utilizes a nonlinear static recreation succession pursued by a mind boggling eigenvalue extraction to decide the screech penchant. The impact of the fundamental operational parameters (braking weight, and erosion coefficient) on the screech inclination is performed. The impact of changing the rotor solidness and back plates firmness under various task condition are explored. The aftereffects of this investigation demonstrate that the screech clamour can be diminished by expanding the rotor solidness and diminishing the back plate firmness of the cushions.

7. Zheng han In this final year project, three-dimensional modeling and meshing using the simulation program ANSYS were successfully implemented. This has allowed for greater flexibility and accuracy in the results achieved. The mechanical performances of a conventional disc brake system and the Perimetria disc brake system under three different simulation environments were studied and compared. Under torsional strength simulation, the Perimetria disc brake performs better with its maximum values of First Principal Stress and Von Mises Stress being significantly lower than those in the conventional brake-disk. Under lateral strength simulation, the Perimetria brake-disk yielded almost similar results to that of the conventional brake-disk. For both the static tests mentioned, the maximum stresses (weak points) in the Perimetria brake-disk occur at the mounting holes. These maximum stresses occur at the holes. This is due to the design of the brake-disk which concentrates the stress on the inner diameter during expansion and contraction. This indicates that the number of potential points for crack initiation is higher.

8. Daniel Das.A, Christo Reegan Raj.V, Preethy.S,Ramya Bharani.G The aim of this paper was to investigate the temperature fields and also structural fields of the solid disc brake during short and emergency braking with four different materials. The distribution of the temperature depends on the various factors such as friction, surface roughness and speed. The effect of the angular velocity and the contact pressure induces the temperature rise of disc brake. The finite element simulation for two-dimensional model was preferred due to the heat flux ratio constantly distributed in circumferential direction. We will take down the value of temperature, and deformation for Generated ought to be more than Braking Torque Required. Because of higher basic of braking torque gigantic extent of powers are related.

III. OBJECTIVES

- To design and develop the mathematical model of the disc for a disc brake system
- To optimize the disc brake by static and thermal analysis.
- To compare the different materials to verify the best material for disc brake.
- To increase the rotor and pad life.

IV. METHODOLOGY

Design considerations and formulae:

Mass of the vehicle = 132 kg
(u)= 27.77 m/s (100 km/h)
speed after braking (v) = 0 m/s
g =9.81m/s2
Coefficient of friction for dry pavement μ=0.45
Diameter of the rotor disc- 241mm
Rotor disc material- cast iron and stainless steel
Coefficient of friction (μ)- stainless steel - 0.5, cast iron - 0.5
Maximum temperature – 350℃, Maximum pressure- 1Mpa

Design of Disc

drill disc rotor

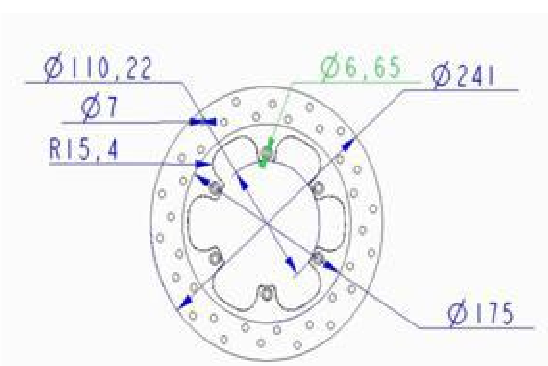

Fig.2. Design disc brake

Fig.3 Modelling of disc brake

Tangential force between the brake pad and rotor:

FTRI= normal force between brake pad and rotor μ = coefficient of friction = 0.5
A = pad brake area = 0.0067 m^2

FTRI = μ.FRI _____________(1)
FRI = (Pmax /2) ×A ____________(2)

FTRI = μ.FRI FTRI = 0.5 × 0.5 × 1E6 × 0.0067 = 1675N
Tangential force between the pad and rotor is equal to FTRI because of the same normal force and material. Brake torque Tb = FT.R FT is the normal forces on the disc brake = 1675N R is the radius of the rotor Tb = FT.R = 1675 × (120× $10e^{-3}$) = 201NM

Brake distance:

Work done = FT __________(4)

FT = normal forces acting on the disc brake. X = distance travelled by vehicle before coming to rest.

Kinetic energy = mv^2. /2 __________(5)

Where, m = mass of the vehicle v = velocity of the vehicle Comparing EQ (4) and EQ (5)
FT.X = mv^2. /2 V = 100 km/h = 27.77 m/s Mass = 132kg X = mv^2/ 2
FT = 132 × 27.772/ (2 × 1675) = 30.38m
Thermal calculations: Heat generated through braking:

Heat generated in rotor (J/S) Q = m. CP. ΔT ---------------EQ (6) Heat flux (W/M2)

Heat flux = Q/A

Calculations on Disc brake:
Strainless Steel:

Heat generated in rotor (J/S) Q = m. CP. ΔT _______(6)

Heat flux (W/M2) Heat flux = Q/A
m = mass of the disc = 1.36kg, ΔT = Temperature difference = 15°C, A = 0.06628 m2
Specific heat = 320 J/kg k,
Q = m. CP. ΔT = 1.36 × 320 × 15 = 6048J
Heat flux = (heat generated/sec)/ Area of the disc = (6528/5)/ 0.06628 = 19698 W/m2
Thermal Gradient = Heat flux / Thermal conductivity = 19698 / 36 = 547.17 k/m

Cast Iron:

Heat generated in rotor (J/S) Q = m. CP. ΔT ________(6)
Heat flux (W/M2) Heat flux = Q/A
m = mass of the disc = 1.22kg, ΔT = Temperature difference = 15°C, A = 0.06628 m2
Specific heat = 380 J/kg k,
Q = m. CP. ΔT = 1.22 × 380 × 15 = 6954J
Heat flux = (heat generated/sec)/ Area of the disc = (6954/5)/ 0.06628 = 20983 W/m2
Thermal Gradient = Heat flux / Thermal conductivity = 20983 / 50 = 419.67 k/m

Table.1. Material Properties for Stainless Steel and Cast Iron

Material Properties	Stainless Steel	Cast Iron
Thermal conductivity(w/m k)	36	50
Density , ρ (kg/m3)	7100	6600
Specific heat , c (J/Kg c)	320	380
Thermal expansion , α (10-6 / k)	0.12	0.16
Elastic modulus, E (GPa)	210	110
Coefficient of friction, μ	0.5	0.5
Film co-efficient h(w/km2)	240	280

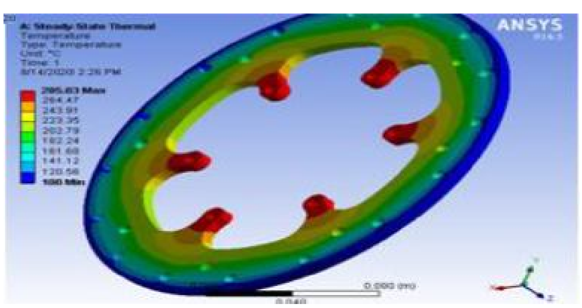

Fig.4. Temperature distribution in SS model

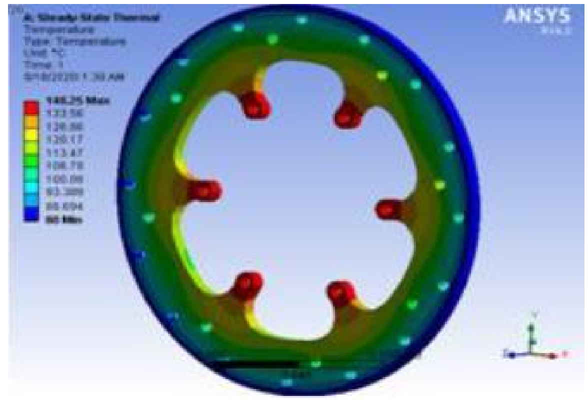

Fig.5. Temperature distribution in Cast Iron model

V. RESULTS & DISCUSSIONS

Table.2. Temperature Distribution

Material	Min	Max
Stainless Steel	80	380
Cast Iron	80	160.5

Table.3. Total Heat Flux

Material	Min	Max
Stainless Steel	398	2*e5
Cast Iron	461	2.39*e5

VI. CONCLUSION

The increase in temperature is maximum in stainless steel when matched up to cast iron. Therefore, on the basis of thermal analysis, cast iron is the finest considerable material for building-up the disc brake. However cast iron disc brake undergo a snag of getting corroded while it comes in contact with moisture and therefore it cannot be used in two wheeler and hence, we consider stainless steel.

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