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Design and Thermal Analysis of Disc Brake for Minimizing Temperature

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Abstract – *These day technologies go beyond us. For automotive field, the technology of engine develops very fast even the system of the bike, car, luxury or comforts everything that develops by the innovation of engineer. Thus, safety is the first important thing we must focus. 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 Bajaj Pulsar 220 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. Hopefully this paper will help everyone to understand Thermal analysis of disc brake rotor and how disc brake work more efficiently, which can help to reduce the accident that may happen in each day. Modeling was done using CATIA V5R21 software and Static and Transient Thermal Analysis was done using ANSYS 15 software.*

Key Words: Disc brake rotor, Thermal analysis etc

1.INTRODUCTION

A brake is a device used to generate an artificial frictional which is applied to moving member of machine, for stopping motion. 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 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.

1.1 CLASSIFICATION OF BRAKES

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

Axial brake

Radial brake

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.

2. PROBLEM DEFINATION AND OBJECTIVES

Extreme thermal environments are an important issue in the design of sliding contact systems such as brakes and clutches. Thermal stresses due to high temperatures may induce a number of unfavorable conditions such as surface cracks and permanent distortions. Frictional heating, thermal deformation and elastic contact in sliding contact systems affect the contact pressure and temperature on the friction surfaces. If the sliding speed is excessively high, these coupled thermal and mechanical behaviors can be unstable leading to localized high temperature contact regions called "hot spots" on the sliding interface.

The appearance of these hot spots is known as frictionally excited thermo elastic instability or TEI and is observed in many practical applications, especially brakes and clutches. Hot spots can cause material damage and thermal crack, and induce an undesirable frictional vibration known as "hot judder" in automotive disk brake systems.

2.1 OBJECTIVES

- Design of the disc for a disc brake system using load analysis, stress analysis and thermal analysis system approach.
- The disc brake rotor is to be rigidity and stability.
- Heat absorption and dispersion.
- Federal safety requirements.
- Increase the rotor and pad life.

3. LITERATURE REVIEW

Before starting with actual working, it's always helpful to study literature and work already carried out in similar field. This study helps to decide project outline and flow. Some research papers, articles are available in which similar type of issues, case studies have discussed. In this chapter, summary of such papers and literature published by various researchers is described.

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 art 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. 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.

4. 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.

5. 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.

6. 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 different pressure condition using analysis software with four materials . The Disc brakes are made up of cast iron.

4. DESIGN PARAMETERS OF DISC BRAKE

Standard parameters of two-wheeler in Bajaj 220cc are Brake rotor material = Grey cast iron (ASTM grade 25) Brake rotor dimension = 240mm

Yield stress of grey cast iron = 110

Mpa Pad brake area = 2000 * 10^{-6} m^2

Maximum pressure = 1 Mpa Maximum

temperature = 250_o C

5. ANALYSIS OF DISC BRAKE

In this paper we analyzed static and transient thermal analysis of disc brake system. In material section of disc brake is to be Grey cast iron. Both analysis has done using ANSYS 15 software.

5.1 STATIC STRUCTURE ANALYSIS

Static structure analysis is the most common application in FEM. Static analysis determines the displacement, stress, strain, force in structure or component caused by loads that do not induce inertia and damping effects. This project deals with the study of stress, deformation on rotor disc under static condition. After completion of finite element model it must constrain and load must be applied to the model. User can define constrain and load in various way. The following figure shows the result of static analysis.

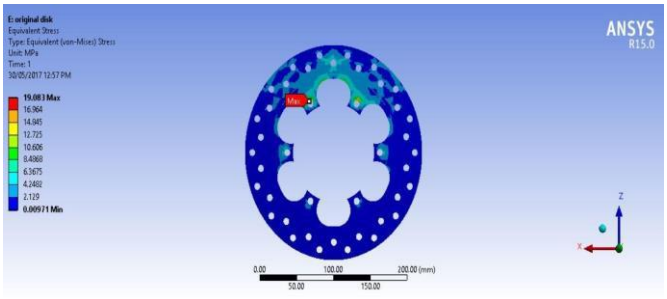

Fig 5.1 Original disc brake

From the above figure shows stress distribution of original disc brake, it is observed that maximum stress is 19.03 Mpa.

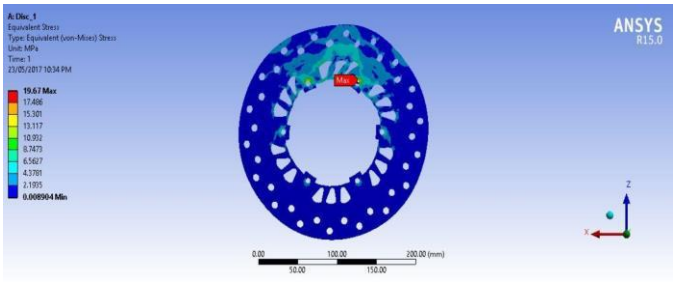

Fig 5.2 New disc 1

Above figure shows the stress distribution of new disc 1, it is observed that maximum stress is 19.67 Mpa.

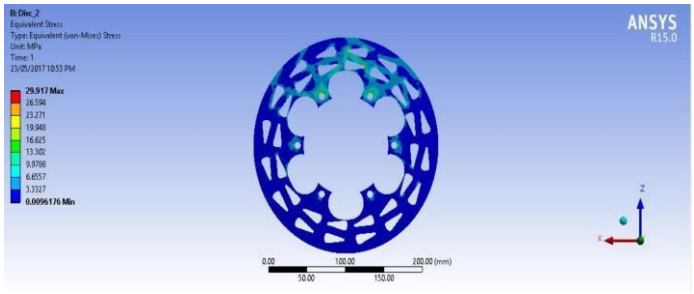

Fig 5.3 New disc 2

Above figure shows the stress distribution of new disc 2, it is observed that maximum stress is 29.917 Mpa.

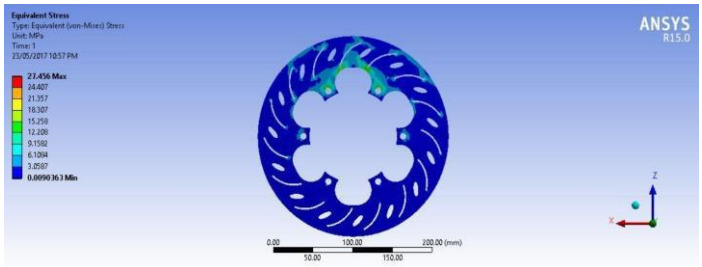

Fig 5.4 New disc 3

Above figure shows the stress distribution of new disc 3, it is observed that maximum stress is 27.456 Mpa.

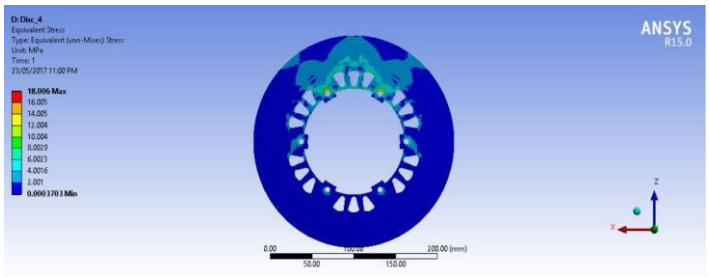

Fig 5.5 New disc 4

Above figure shows the stress distribution of new disc 4, it is observed that maximum stress is 18 Mpa.

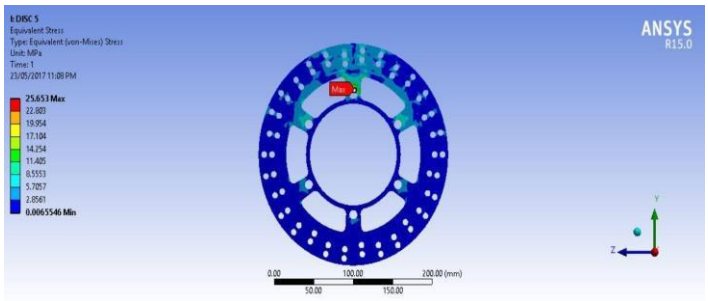

Fig 5.6 New disc 5

Above figure shows the stress distribution of new disc 5, it is observed that maximum stress is 25.653 Mpa.

From computational analysis result for different design it shows that new disc 5 maximum stresses of 25.653 Mpa respectively. So, design is safe for Grey cast iron material.

5.2 TRANSIENT THERMAL ANALYSIS

Transient thermal analysis is used to determine temperature and other thermal quantities that change over time.The change in temperature distribution over time is important in many applications such as in quenching analysis for heat treatment. Also of interest are the temperature distribution results in thermal stresses that can cause the failure. In such cases temperature from the transient thermal analysis for thermal stress evaluation. Heat flux is applied for different design structure discs is 0.0211 W/mm2.The following figure shows the result of transient analysis in various discs.

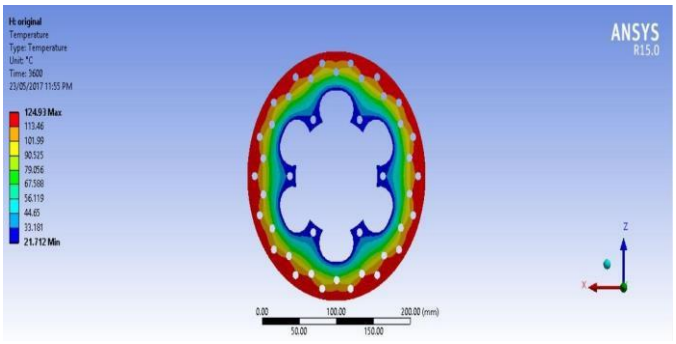

Fig 5.7 Transient thermal analysis on original disc

As shown in above figure transient thermal analysis was conducted on the disc and maximum temperature observed is 124.93oC and minimum temperature observed is 21.712oC.

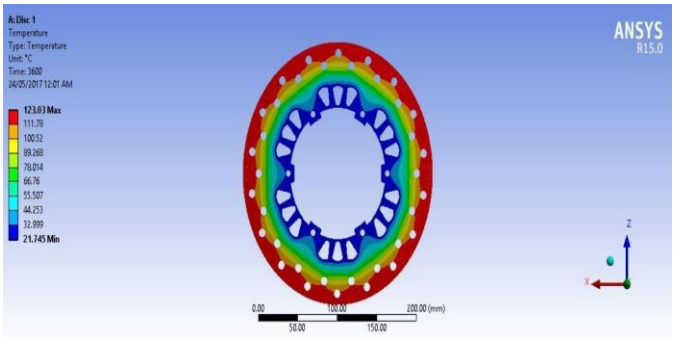

Fig 5.8 Transient thermal analysis on new disc 1

As shown in above figure transient thermal analysis was conducted on the disc and maximum temperature observed is 123.03oC and minimum temperature observed is 21.745oC.

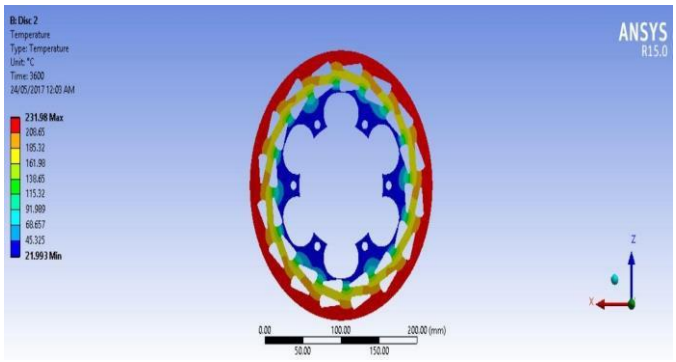

Fig 5.9 Transient thermal analysis on new disc 2

As shown in above figure transient thermal analysis was conducted on the disc and maximum temperature observed is 238.98oC and minimum temperature observed is 21.99oC.

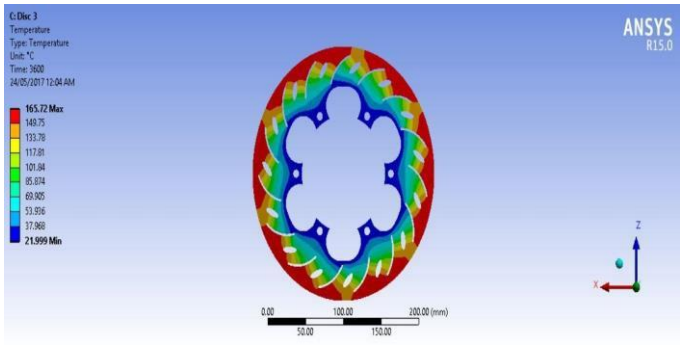

Fig 5.10 Transient thermal analysis on new disc 3

As shown in above figure transient thermal analysis was conducted on the disc and maximum temperature observed is 165.72oC and minimum temperature observed is 21.99oC.

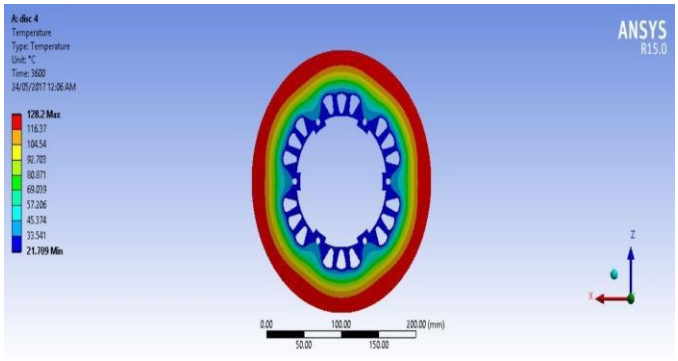

Fig 5.11 Transient thermal analysis on new disc 4

As shown in above figure transient thermal analysis was conducted on the disc and maximum temperature observed is 128.2oC and minimum temperature observed is 21.70oC.

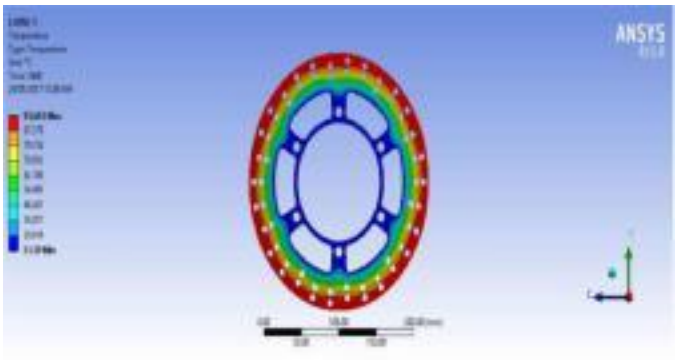

Fig 5.12 Transient thermal analysis on new disc 4

As shown in above figure transient thermal analysis was conducted on the disc and maximum temperature observed is 95.603$_0$C and minimum temperature observed is 21.59$_0$C

From transient thermal analysis for different design it shows that the new disc 5 generates the minimum temperature 95.603$_0$C. Hence new disc 5 is the best among all.

6. RESULT AND COMPARISON

6.1 STATIC STRUCTURE

Table 6.1 comparison of stress and deformation for different discs

	Stress	Deformation
Original disc	19.083	0.003695
New disc 1	19.67	0.003829
New disc 2	29.917	0.00568
New disc 3	27.456	0.005342
New disc 4	18.006	0.003519
New disc 5	25.653	0.00585

Above table shows the comparison of stresses between different discs where the maximum stress developed in original disc is 19.083 Mpa while that in the new disc 5 is 25.653 Mpa which is well below the yield limit of 110 Mpa. Hence the design is safe.

6.2 TRANSIENT THERMAL ANALYSIS

Table 6.2 Comparison of temperature and weight for different discs

	Temperature($_0$C)	Weight (kg)
Original disc	124.93	0.985
New disc 1	123.03	1.0811
New disc 2	231.98	0.877
New disc 3	165.72	0.965
New disc 4	128.2	1.148
New disc 5	95.603	0.895

Above table 6.2 shows the comparison of temperature and weight in different discs as shown the temperature maximum generated in original disc is 124.93$_0$C while that in new disc 5 is 95.603$_0$C. As it seen the weight of original disc is 0.985kg while that of new disc 5 is 0.895kg.

7. CONCLUSIONS

The above study can provide a useful design and help to improve the brake performance of disc brake system. From the above result, we can say that minimum temperature distribution occurs in modify (new disc 5) as compare to actual standard Bajaj pulsar 2wheeler and other new discs. Also for structural analysis result of computational we found the new brake disc design is safe based on strength and rigidity criterion. On the basis of various results gathered from the analysis, it is decided that grey cast iron is the suitable material for disc brake. New disc 5 is good brake disc compared to original brake disc of Bajaj pulsar of two-wheeler and other new disc brake for heat dissipation. New disc 5 carrying high brake force during running condition without any cracks, buckling.

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