ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 7, July 2015

Thermal and Structural Analysis of Disc Brake with Square / Circular Groove for Two Wheeler

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Abstract: Without brake system in the vehicle will put a passenger in unsafe position. Therefore, it is a must for all vehicles to have proper brake system. Due to critical system in the vehicle, many of researchers have conducted a study on brake system and its entire component. In this paper study has conducted on square, circular grooved and normal disc brake rotor of passenger vehicle with full load of capacity. The study is more likely concern of heat and temperature distribution on disc brake rotor. Thermal and structural analysis has been carried through the heat transfer analysis where to predict the worse case scenario and temperature behaviors of disc brake rotor. Further, finite element analysis, ANSYS software has been used in order to identify the temperature distributions and behaviors of disc brake rotor in steady state responses. The results have been compared for better justification. Thus, the results provide better understanding on the thermal characteristic of disc brake rotor and assist the automotive industry in developing optimum and effective disc brake rotor of two wheeler.

Key Words: Disc brake rotor, square groove, circular groove, Thermal and structural analysis, ANSYS

1. INTRODUCTION

A brake is a device by means of which artificial frictional resistance is applied to moving machine member, in order to stop the motion of a machine. In the process of performing this function, the brakes absorb either kinetic energy of the moving member or the potential energy given up by objects being lowered by hoists, elevators etc. The energy absorbed by brakes is dissipated in the form of heat. This heat is dissipated in the surrounding atmosphere to stop the vehicle, so the brake system should have following requirements:

The brakes must be strong enough to stop the vehicle with in a minimum distance in an emergency.

The driver must have proper control over the vehicle during braking and vehicle must not skid. The brakes must have well anti fade characteristics i.e. their effectiveness should not decrease with constant prolonged application. The brakes should have well anti wear properties.

2. PROBLEM STATEMENT

The thermal and structural analysis on the disc brake of 5mm thickness is made of gray cast iron with and without Groove. The dimensions of disc brake are given in Fig.1

3. METHODOLOGY

The following methodology is adopted in the paper to meet the above mentioned objective.

- Import the geometry of disc brake to ANSYS
- Meshing of the geometry using tetra mesh in ANSYS
- Applying material properties, boundary conditions
- Performing Thermal and Structural response analysis.

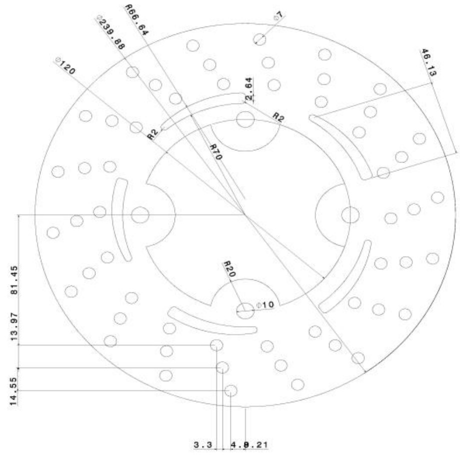

Fig1: Dimensions of the disc brake

4. MATERIAL PROPERTIES OF GRAY CAST IRON

- Thermal Conductivity = 52e-3 W/mm^{0}K
- Specific Heat = 447 J/kg ^{0}K
- Yield Strength = 275.7 MPa
- Tensile Strength = 413.6 MPa
- Elastic Modulus = 1.9e5 MPa
- Poisson's Ratio = 0.27

5. OBJECTIVE OF THE PRESENT STUDY

The present investigation is aimed to study:

1. Stability and rigidity (for this Thermal analysis and coupled structural) analysis is carried out on a given disk brake rotor.
2. Best combination of parameters of disk brake rotor like Groove of Square and circular and material there by a best combination is suggested.

DOI 10.17148/IARJSET.2015.2716

ISSN (Online) 2393-8021
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6. ELEMENT DESCRIPTION

6.1. Thermal element: SOLID70 Element Description

SOLID70 has a 3-D thermal conduction capability. The element has eight nodes with a single degree of freedom, temperature, at each node. The element is applicable to a 3-D, steady-state or transient thermal analysis. The element also can compensate for mass transport heat flow from a constant velocity field

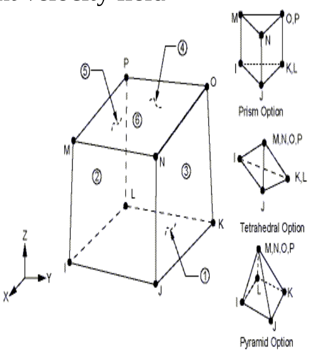

Fig2: SOLID70 Geometry

6.2. Structural element: SOLID185 Element Description

SOLID185 is used for 3-D modeling of solid structures. It is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, hyper elasticity, stress stiffening, creep, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elasto-plastic materials, and fully incompressible hyper elastic materials.

7. FINITE ELEMENT ANALYSIS

The analysis is done in ANSYS by taking the Brake Efficiency of 30% and hence the distributions of braking torque between the front and rear axle is 70:30.

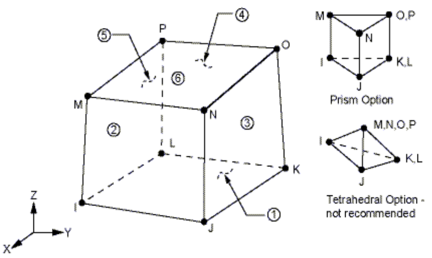

Fig3:SOLID185 Geometry

Thus Load Calculations:
Area of the disc break = 43344.6 mm^2
Load = 520103.52 N
Pressure = load/Area=1 MPa
Temperature = 100^0C
Convection =300E-6 W/mm^2 ^{0}K
Bulk Temperature = 50^0C
The procedure for doing analysis is as follows:
First thermal analysis is performed by importing geometric model from CatiaV5 R20 and applying SOLID70 as element, and then the model is meshed. The temperature of 100^0C, Convection of 300E-6 W/mm^2 ^{0}K, Bulk Temperature 50^0C are applied as boundary conditions and then is solved. The nodal temperatures are plotted. For doing structural analysis the element is switched from thermal to structural analysis. Selecting SOLID185 element assigning material properties: young's modulus as 1.9e5 N/mm^2 , poisson's ratio as 0.27, and thermal expansion as 10.8e-6. Applying displacement constraints and pressure as 1Mpa. Then browse .RthFile from thermal Analysis and solved to get the von-mises stresses.

8. GEOMETRIC MODELING

CatiaV5 R20 is an interactive Computer- Aided Design and Computer Aided Manufacturing system is used for modeling of disc brake rotor without groove, with square and circular groove. Then the model is imported in to ANSYS for doing analysis.

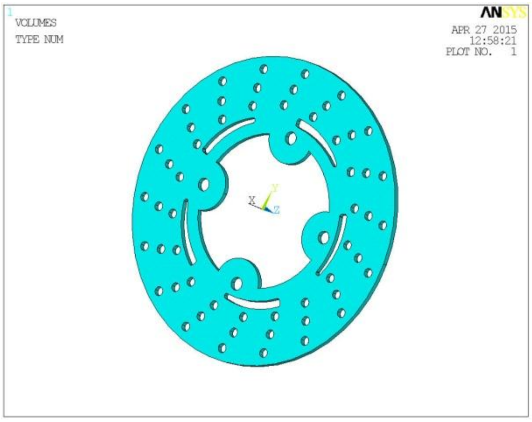

Fig4: Geometric model of disc brake without groove

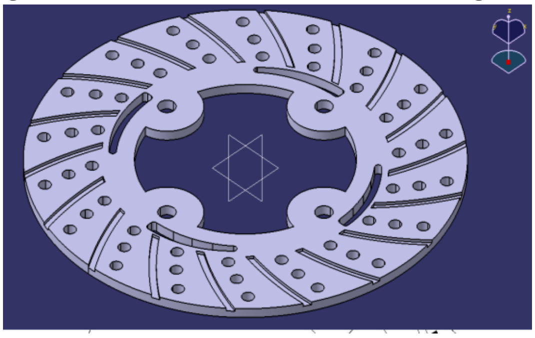

Fig.5: Geometric model of disc brake with square groove

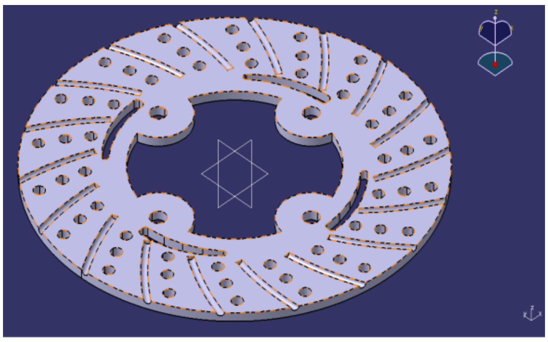

Fig.6: Geometric model of disc brake with circular groove

9. LOADS AND BOUNDERY CONDITIONS IN ANSYS

ISSN (Online) 2393-8021
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International Advanced Research Journal in Science, Engineering and Technology
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As shown in Fig.7 the entire surface, S, of the disk has three different regions including S1 and S2. On S1 heat flux is specified due to the frictional heating between the pads and disk, and S2 is defined for the convection boundary. The rest of the region is either temperature specified or assumed to be insulated.

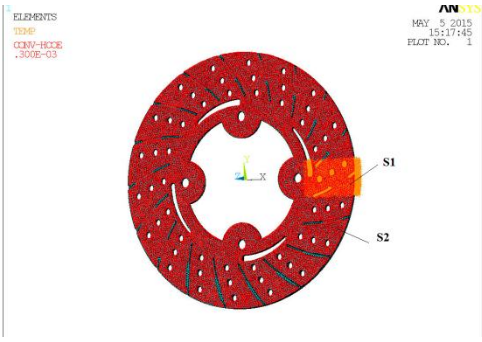

Fig 7: Thermal Boundary Conditions of disc brake

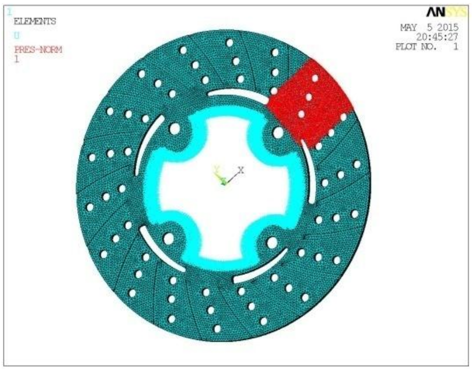

Fig8: Structural boundary conditions of disc brake

10. RESULS AND DISSCUSSIONS

10.1. RESULTS OF GRAY CAST IRON WITHOUT GROOVE

After applying loads and boundary conditions the problem is solved. The following figures show nodal temperature distributions, deformations and von-mises stresses in the disc brake without groove.

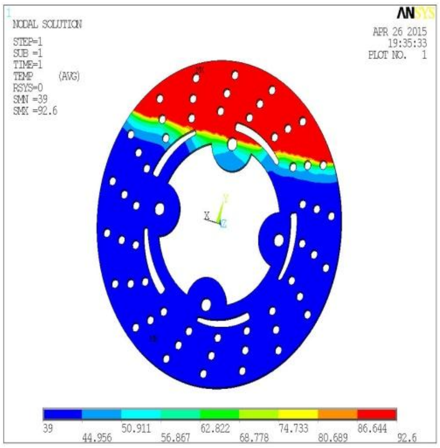

Fig9: Nodal temperature of disc brake

Fig.9 Shows minimum and maximum temperature distribution Without Groove. Minimum value is 39^0C and maximum value is 92.6^0C

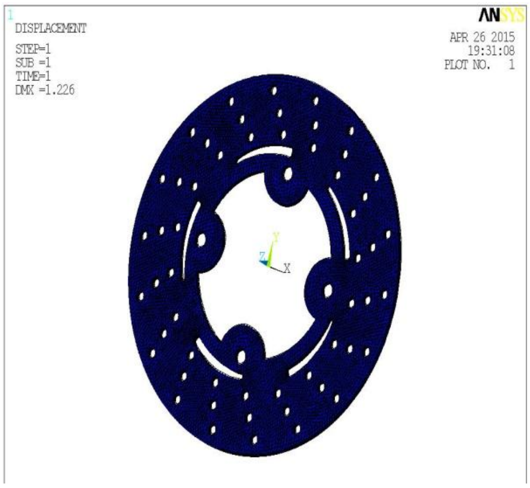

Fig10: Deformation of disk brake

Fig.10 Shows Total Deformation of Disc Brake. Deformation is 1.226 mm Without Groove.

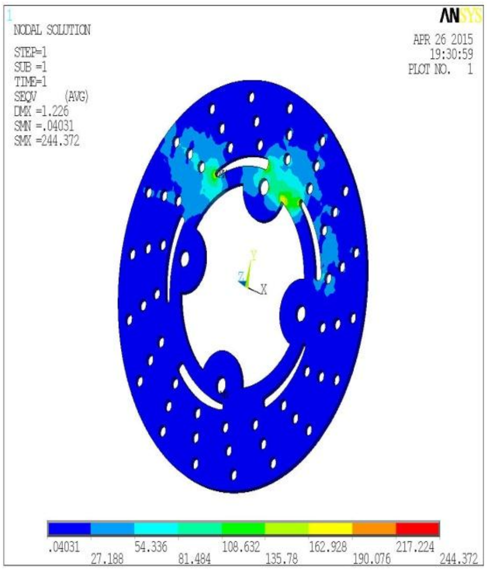

Fig.11: Von-mises stress of disc brake

Fig.11 Shows Minimum and Maximum Von-mises Stress distribution Without Groove. Minimum value is 0.04031 MPa and Maximum value is 244.372 MPa.

10.2. RESULTS OF GRAY CAST IRON WITH SQUARE GROOVE OF 2mm

Fig.12 Shows Minimum and Maximum temperature distribution with Square Groove of 2 mm. Minimum value is 35.017^0C and Maximum value is 70^0C.

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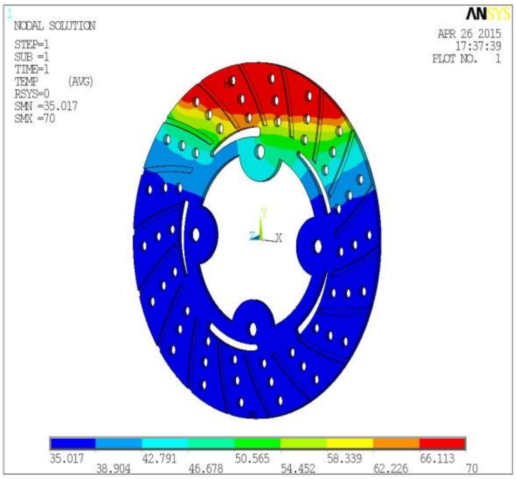

Fig12: Nodal temperature of disc brake with groove of 2mm

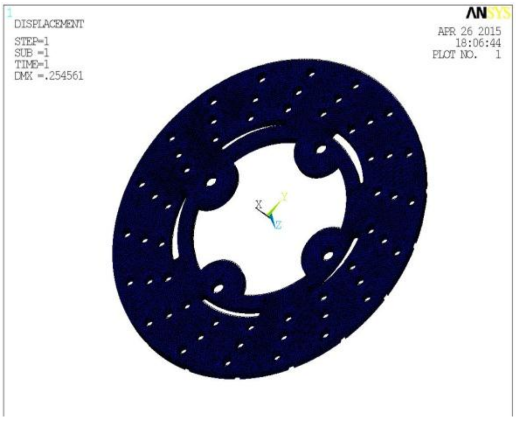

Fig13: Deformation of disk brake with groove of 2mm

Fig.13 Shows Total Deformation of Disc Brake. Deformation is 0.254561 mm with Square Groove of 2 mm.

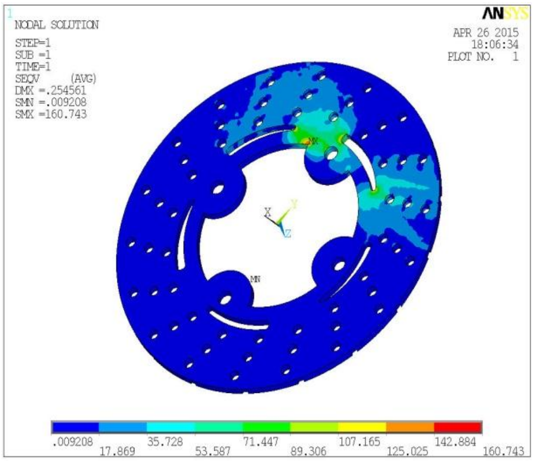

Fig14: Von-mises stress of disc brake with groove of 2mm

Fig.14 Shows Minimum and Maximum Von- mises Stress distribution with Square Groove of 2 mm. Minimum value is 0.009208 MPa and Maximum value is 160.743 MPa.

10.3. RESULTS OF GRAY CAST IRON WITH SQUARE GROOVE OF 1.5 mm

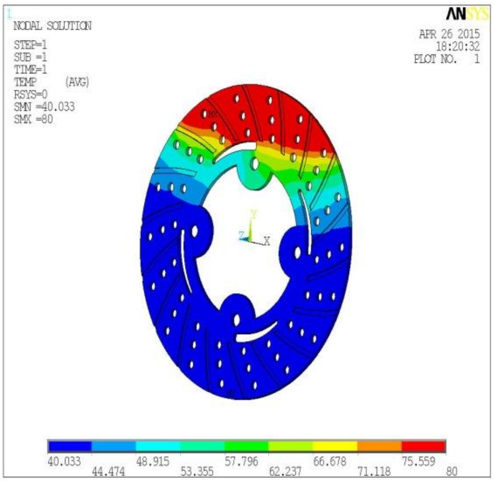

Fig.15: Nodal temperature of disc brake with square groove of 1.5mm

Fig.15 Shows Minimum and Maximum Temperature distribution with Square Groove 1.5 mm. Minimum value is 40.033^{0}C and Maximum value is 80^{0}C

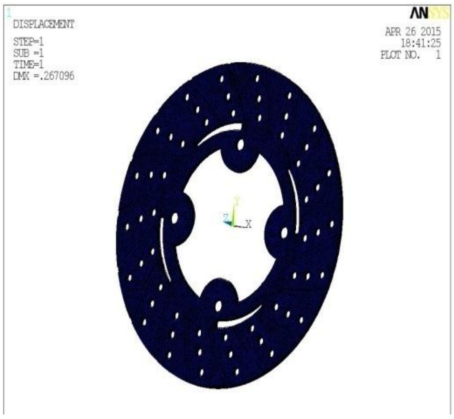

Fig16: Deformation of disk brake with square groove of 1.5mm.

Fig16. Shows Total Deformation of Disc Brake. Deformation is 0.267096 mm with Square Groove of 1.5 mm.

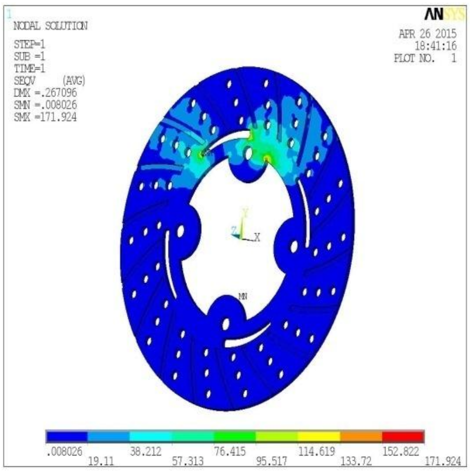

Fig.17 Von-mises stress of gisc brake with square groove of 1.5mm

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
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Fig.17 Shows Minimum and Maximum Von misses Stress distribution with Square Groove of 1.5mm.Minimum value is 0.008026 MPa and Maximum value is 171.924 MPa.

10.4. RESULTS OF GRAY CAST IRON WITH CIRCULAR GROOVE OF 2 mm

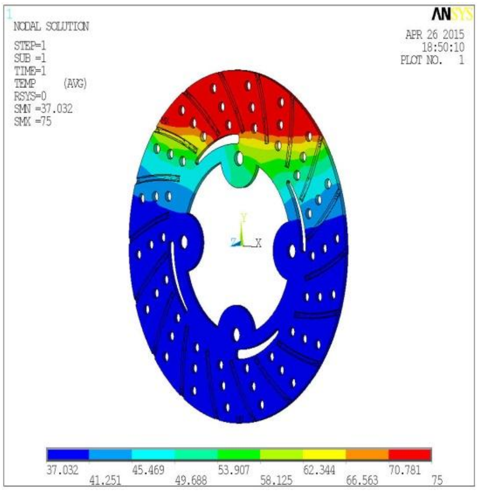

Fig18: Nodal temperature of disc brake with circular groove of 2mm.

Fig.18 Shows minimum and Maximum temperature distribution with circular groove of 2 mm. Minimum value is 37.032^{0}C and Maximum value is 75^{0}C.

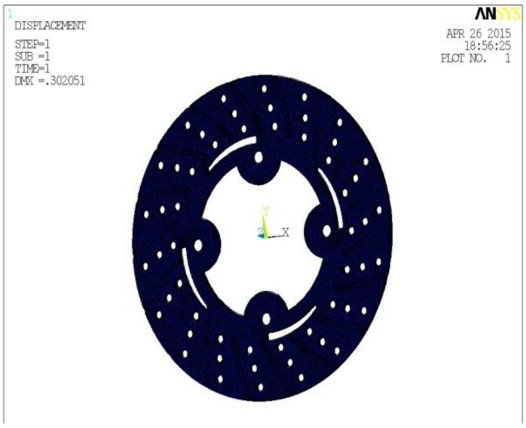

Fig19: Deformation of disk brake with circular groove of 2mm.

Fig.19 Shows Total Deformation of Disc Brake. Deformation is 0.302051 mm with Circular Groove of 2 mm of 0.302051 mm.

Fig20 Shows Minimum and Maximum Vonmises Stress distribution with Circular Groove of 2 mm. Minimum value is 0.11331MPa and Maximum value is 211.696 MPa

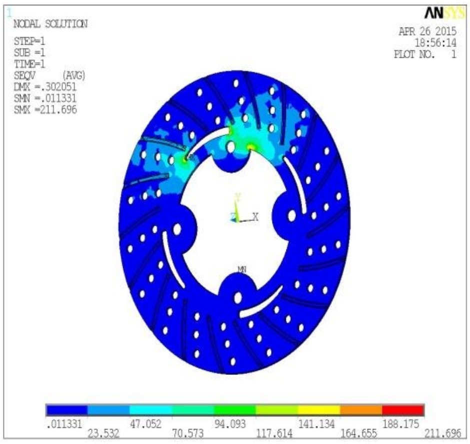

Fig20: Von-mises stress of disc brake with circular groove of 2mm.

10.5. RESULTS OF GRAY CAST IRON WITH CIRCULAR GROOVE OF 1.5 mm

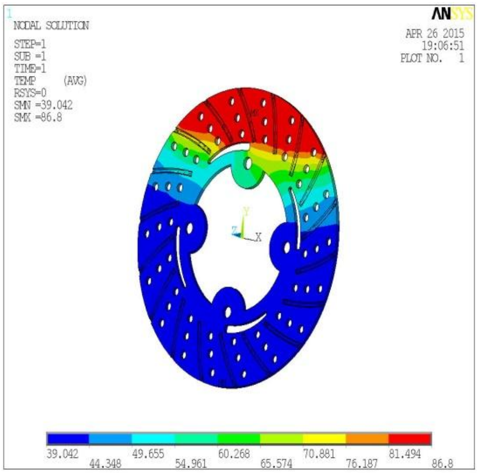

Fig21: Nodal temperature of disk brake with circular groove of 1.5 mm

Fig.21 Shows Minimum and Maximum Temperature distribution with Circular Groove of 1.5 mm. Minimum value is 39.042^{0}C and Maximum value is 86.8^{0}C

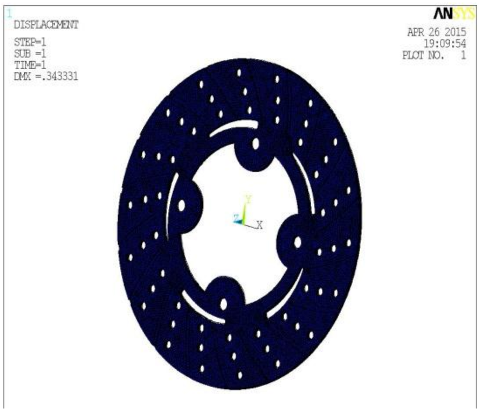

Fig22: Deformation of disk brake with circular groove of 1.5 mm

Fig22 Shows Total Deformation of Disc Brake. Deformation is 0.343331 mm with Circular Groove of 1.5 mm of 0.343331 mm

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ISSN (Print) 2394-1588

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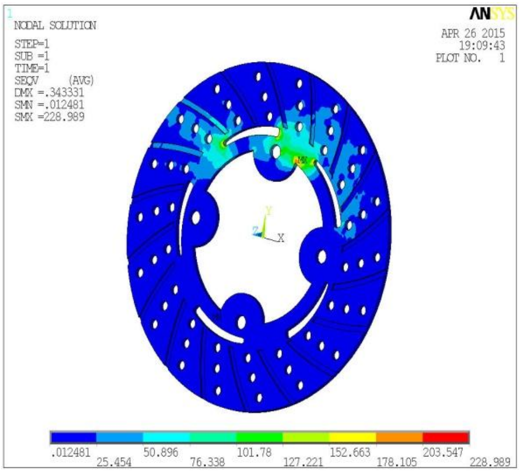

Fig23: Von-mises stress of disk brake with circular groove of 1.5 mm

Fig.23 Shows minimum and maximum Vonmises Stress distribution with Circular Groove of 2 mm. Minimum value is 0.012481MPa and Maximum value is 228.989 MPa.

Parameters	With out Groove	With Square Groove of 2mm	With Circular Groove of 2mm	With Square Groove of 1.5mm	With Circular Groove of 1.5mm
Nodal temperature (^{0}C)	92.6	70	75	80	86.8
Deformation (mm)	1.226	0.254	0.302	0.267	0.343
Von-mises Stress(MPa)	244.3	160.7	211.6	171.9	228.9

Table1: Nodal temperature, deformation and von-mises stresses in the brake

11. CONCLUSIONS

In this paper, the Thermal and Structural analysis of disk brakes with and without Groove has been performed. The effect of without groove, with groove, with square and with circular shapes is examined. From results we can say that all the values obtained from the structural analysis are less than their allowable values. Hence the brake disk design is safe based on the strength and rigidity criteria. Comparing the structural and thermal results obtained from analysis, it is recommended that disk brake with 2mm of square shape, material: Gray Cast Iron is the best possible combination for the present application.

12. FUTURE SCOPE

In the present investigation of thermal analysis of disk brake with and without Groove, with only Temperature and Convection is analyzed by ANSYS. As future work, disk brake with and without Groove, Thermal Transient analysis can be done still becomes complicated by considering variable thermal conductivity, variable specific heat and non uniform deceleration of vehicle. This can be considered for the future work.

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