Modelling And Structural Analysis of Shape Optimization In Disc Brake Rotor

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Abstract- *In this project disc brake rotor with vertical hole on the thickness region was designed by using CATIA modelling software. Thermal analysis was carried out on ANSYS 16.2 simulation software in order to predict the thermal deformation and total heat flux established in the disc. Crack development reduction was achieved by generating hole on inner surface of disc which was allowing atmospheric air and reducing the thermal stress. Here new design safety factor was proven by Ansys structural analysis. The comparison was made between existing design and new design results was obtained from FEM was done and all the values obtained from the analysis are less than their allowable values. Hence best suitable design, disc is suggested based on the performance.*

Keywords- Disc brake, CATIA, thermal stress, structural analysis, ANSYS.

I. INTRODUCTION

The disc brake is a wheel brake which slows rotation of the wheel by the friction caused by pushing brake pads against a brake disc with a set of calipers. The brake disc (or rotor in American English) is usually made of cast iron but may in some cases be made of composites such as reinforced carbon–carbon or ceramic matrix composites. This is connected to the wheel and/or the axle. To stop the wheel, friction material in the form of brake pads, mounted on a device called a brake caliper, is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop. Brakes convert motion to heat, and if the brakes get hot, it become less effective, a phenomenon known as brake fade. Most drum brake designs have at least one leading shoe, which gives a servo-effect. By contrast, a disc brake has no self-servo effect and its braking force is always proportional to the pressure placed on the brake pad by the braking system via any brake servo, braking pedal or lever, this tends to give the driver better "feel" to avoid impending lockup. Drums are also prone to "bell mouthing", and trap worn lining material within the assembly, both causes of various braking problems. The brake disc is the component of a disc brake against which the brake pads are applied. The material is typically grey iron a form of cast iron. The design of the disc varies somewhat. Some are simply solid, but others are hollowed out with fins or vanes joining together the disc's two contact surfaces (usually included as part of a casting process). The weight and power of the vehicle determines the need for ventilated discs. The "ventilated" disc design helps to dissipate the generated heat and is commonly used on the more-heavily-loaded front discs.Transient Thermal and Structural Analysis of the Rotor Disc of Disk Brake was aimed at evaluating the performance of disc brake rotor under severe braking conditions and there by assisted in disc rotor design and analysis. Due to heat generation at each braking phase of dry contact leads to development of crack in the rotor disc. The main purpose of this study is to analyze the thermos mechanical behavior of dry contact of the brake disc during the braking phase.

II. LITERATURE REVIEW

Daanvirkarandhir et al This paper is focused on the rise in temperature of an automotive disc brake at the time of braking and its durability using finite element method .the rotor was further loaded with thermos mechanical cyclic stresses which used to analyze the durability and fatigue factor of safety of disc .the influence in disc rotor geometry holes and air foil vents in comparison to a simple flange type disc were studied and their effect on maximum temperature rise and disc durability has been investigated and conducting FEM techniques in solid Works and ANSYS respectively. **Ali Belhocine et al**In this project the study is to analyze the thermomechanical behavior of the dry contact between the brake disc and pads during the braking phase. the thermal structural analysis is then used with coupling to determine the deformation established and the von mises stress in the disc, the contact pressure distribution. **Kamana et al** Themain aim of this paper is to model a disc brake used. coupled field analysis (structural) is done on the disc brake. the materials used are alloy steel, aluminum alloy and cast alloy steel. Disc brake bare to large thermal stresses during regular braking and extra ordinary thermal stresses during hard braking.**Manjunathtv et al**in this paper transient thermal and structural analysis of the rotor disc of disc brake aimed at evaluating the performance of disc brake rotor. The coupled thermal structural analysis is used to determine the deformation and the von misses stress established in the disc for the both solid and ventilated disc with two different material to enhance performance of the rotor disc.

Subramanian p et al The finite element model comprises of both ventilated disc brake and hub. The brake disc and hub are modelled using 3D tetrahedral elements. The material cast iron is taken for both disc and hub. Rigid body elements and beam elements are used for modelling the bolts. The shell coat is provided over the model for transmitting the brake torque effectively. The bolt preload is applied using thermal effects**.Hui lüa et al**In this paper, a hybrid probabilistic and interval model is introduced to deal with the uncertainties existing in a disc brake system for squeal reduction. The uncertain param- eaters of the brake system with enough information are treated as probabilistic variables, while the parameters with limited information are treated as interval variables. To improve computational efficiency.**Qifeijian et al** In this paper, and temperature curves of brake disc in radial and circumferential directions were obtained. By comparison, the experimental values and simulation values were basically equal. The rationality of the selected finite element analysis (FEA) was attributed, which provided a better theoretical basis for further experimental**Manthanvidiya et al**This paper deals with the theory behind thermal analysis of the brake, the method used to calculate the conversion of the car's kinetic energy to the brake's heat energy, to find the convection coefficient available due to the air flow on the car and to determine the overall temperature rise on the brake disc.

III. METHODOLOGY

The following methodology is being adopted to carry out the above-mentioned objectives:

- CAD model was designed by CATIA V5
- Using ANSYS the overall thermal distribution is computed and tried to validate with classical theory.
- Using these equivalent properties of the composite the natural frequency computations are done.

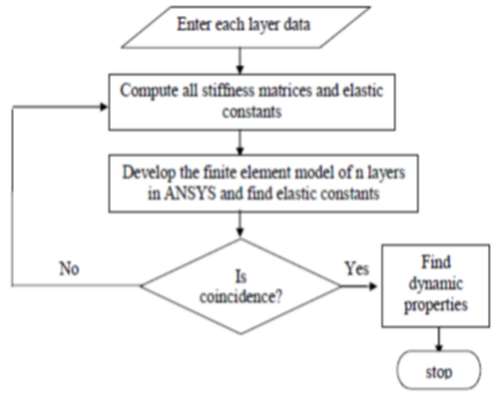

Fig 5.1 Flow chart of present methodology

A. Conceptual design and modelling

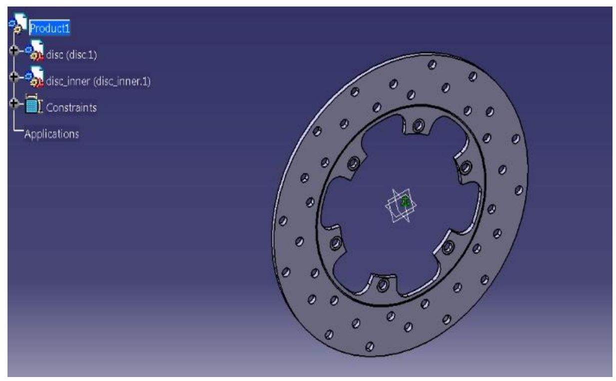

Fig 1. Isometric view

B. Modelling of new disc brake

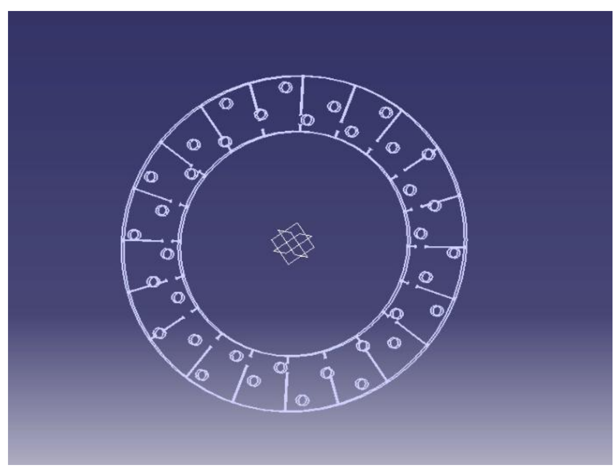

Fig.2. Wireframe model

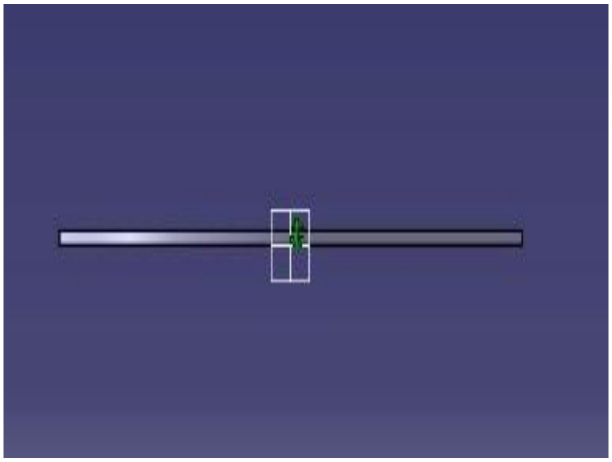

Fig .3. Thickness side view

C. Introduction to FEA

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company can verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction.Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition. FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of an area. In practice, a finite element analysis usually consists of three principal steps.

D. Preprocessing

The user constructs a model of the part to be analyzed in which the geometry is divided into several discrete sub regions, or elements," connected at discrete points called nodes." Certain of these nodes will have fixed displacements, and others will have prescribed loads. These models can be extremely time consuming to prepare, and commercial codes vie with one another to have the most user-friendly graphical “preprocessor" to assist in this rather tedious chore. Some of these preprocessors can overlay a mesh on a preexisting CAD file, so that finite element analysis can be done conveniently as part of the computerized drafting-and-design process.

E. Analysis

The dataset prepared by the preprocessor is used as input to the finite element code itself, which constructs and solves a system of linear or nonlinear algebraic equations [K] [U] = [F] Where u and f are the displacements and externally applied forces at the nodal points. The formation of the K matrix is dependent on the type of problem being attacked, and this module will outline the approach for truss and linear elastic stress analyses. Commercial codes may have very large element libraries, with elements appropriate to a wide range of problem types. One of FEA's principal advantages is that many problem types can be addressed with the same code, merely by specifying the appropriate element types from the library

F. Postprocessing

In the earlier days of finite element analysis, the user would pore through reams of numbers generated by the code, listing displacements and stresses at discrete positions within the model. It is easy to miss important trends and hot spots this way, and modern codes use graphical displays to assist in visualizing the results. Typical postprocessor display overlays colored contours representing stress levels on the model, showing a full field picture like that of photo elastic or moiré experimental results.

G. Introduction to Ansys

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behavior of these elements and solves them all; creating a comprehensive explanation of how the system acts.

H. Geometry of disc brake

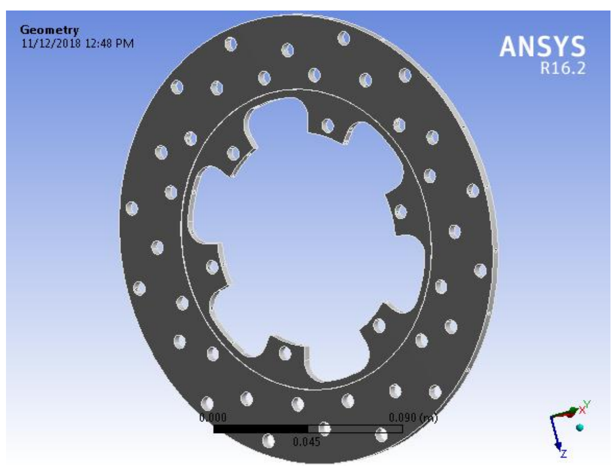

Fig .4. Geometry of disc design

The above diagram shows that existing design of disc brake rotor contains152 mm inner diameter and 230mm outer diameter with the thickness of 4 mm.

I. Temperature distribution

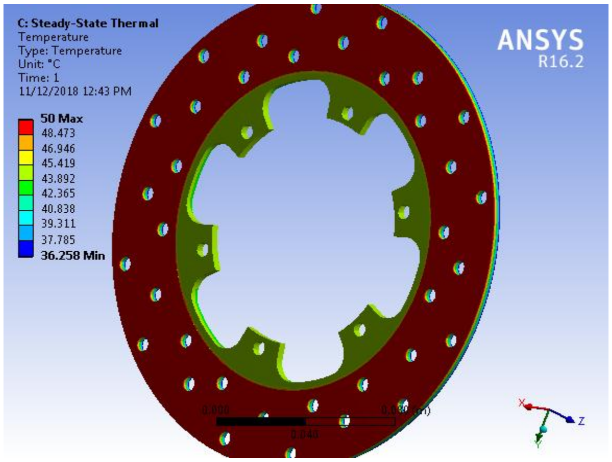

Fig.5. Temperature Distribution of existing design

In Steady state thermal analysis, the Temperature distribution takes places from maximum of 50 Degree Celsius and it reduces to 36 degree Celsius of existing design of disc brake rotor.

J. Total heat flux distribution

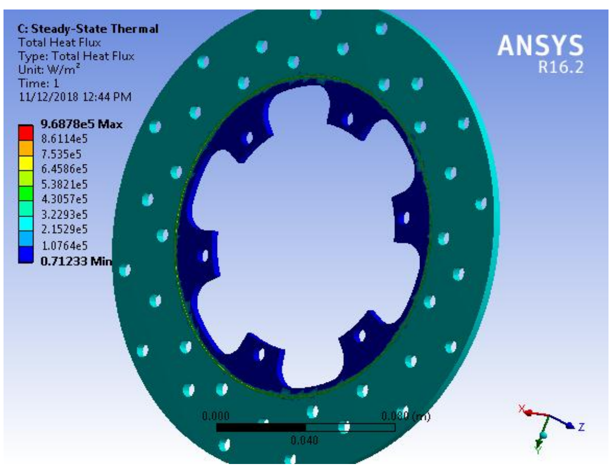

Fig.6. Total heat flux of existing design

The amount of heat transferred per unit area time from to a surface is maximum of 9.6878e5 and 0.71233 minimum.

K. Total deformation of existing design

The displacement allows to check deformation in three direction XYZ. the total deformation of existing design of maximum of 1.5858e-5.

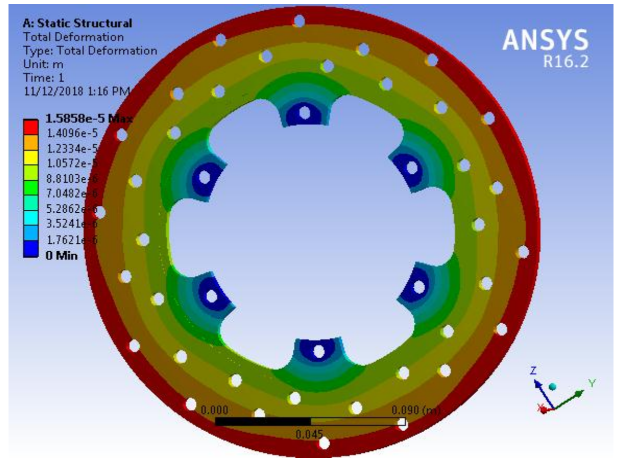

Fig .7. Total deformation of existing design

L. Static structural

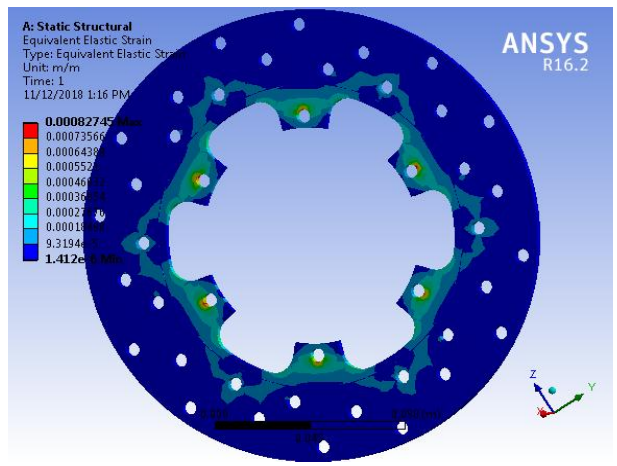

Fig .8. Equivalent Elastic strain of existing design

The Deformed Force is removed the form of strain in which the distorted body of disc brake rotor returnits original shape and size of maximum value of 0.00082745 and minimum of 1.412e-6.

M. Equivalent von mises stress

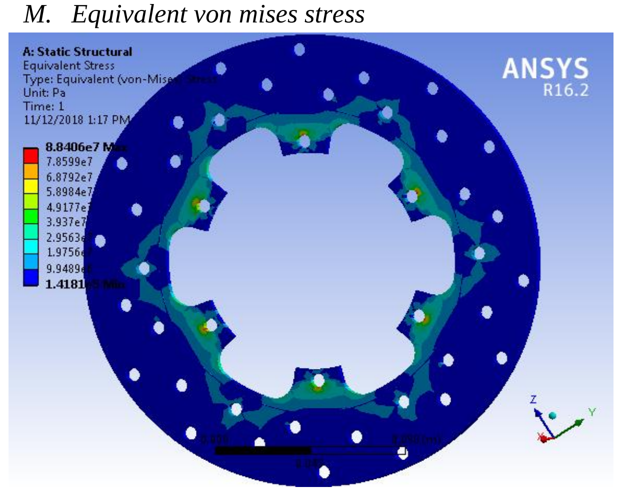

Fig.9. Equivalent von mises stress of existing design

The maximum distortion of energy suggests that yielding of a ductile material begins from 1.4181e5 minimum which second stress of critical value of 8.8406e7maximum.

N. Geometry of new design

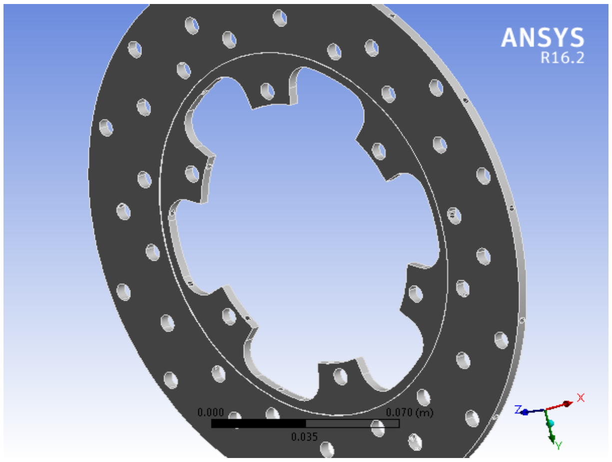

Fig.10. Geometry of New Design in thickness section

The New design of disc brake rotor designed by generating hole on thickness region of about 2mm diameter with slots of 20.

O. Geometry of wire frame design

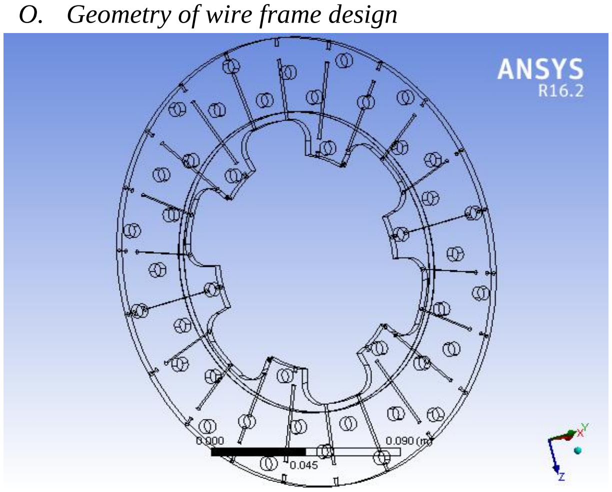

Fig.11. Wire frame model

The wire frame model represents that the creating a hole on thickness region which passes through already existing holes on longitudinal direction

P. Temperature distribution of new design

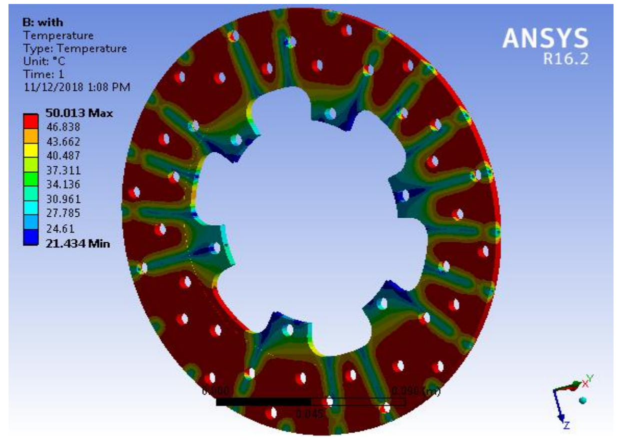

Fig.12. Temperature distribution of new design

In Steady state thermal analysis, the Temperature distribution takes variation from maximum of 50.013 Degree Celsius and it reduces to 21.434 degree Celsius of new design of disc brake rotor

Q. Total deformation of new design

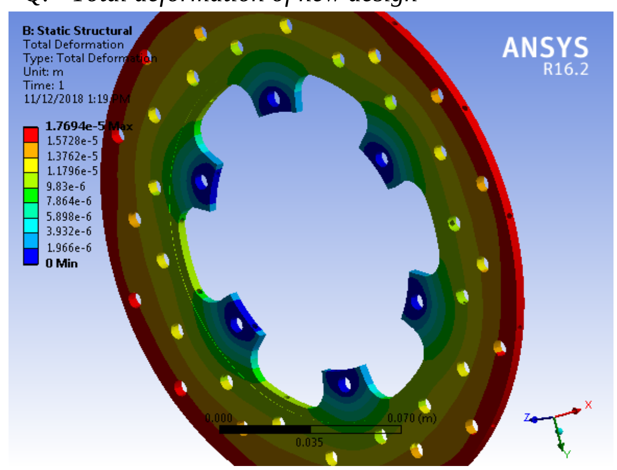

Fig.13. Total deformation of new design

The displacement allows to check deformation in three direction XYZ. the total deformation of new design of maximum of 1.7694e-5.

R. Equivalent elastic strain of new design

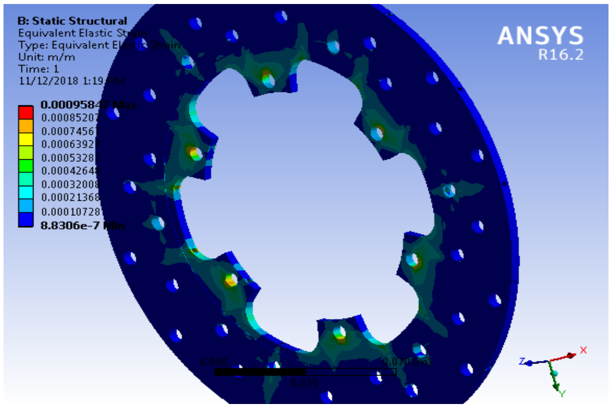

Fig.14. Equivalent Elastic Strain of New design

The Deformed Force is removed the form of strain in which the distorted body of disc brake rotor return its original shape and size of maximum value of 0.0009584 and minimum of 8.8306e-7.

S. Equivalent von-mises stress of new design

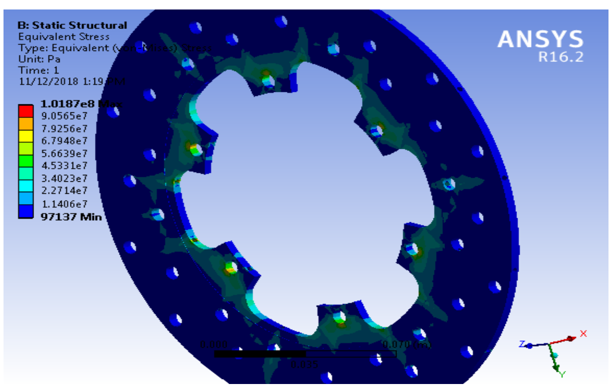

Fig.15. Equivalent von mises stress of new design

The maximum distortion of energy suggests that yielding of a ductile material begins from 97137 minimum which the second derivative stress reaches of critical value of 1.0187e8 maximum.

IV. RESULTS AND DISCUSSION

Table 1.Temperature distribution of existing and new design

DESIGN	MAX. TEMPERATURE	MIN. TEMPERATURE
EXISTING	50	36.258
NEW	50	21.434

The temperature distribution of existing and new the design which compares to existing design. The new design of disc brake rotor shows minimum temperature.

Table 2. Total thermal deformation of existing and new design

DESIGN	MAX HEAT DEFORMATION
EXISTING	1.5858e-5
NEW	1.7694e-5

The maximum total deformation for new design is greater than existing design

Table 3.Equivalent elastic strain of existing and new design

DESIGN	MAX. STRAIN	MIN. STRAIN
EXISTING	0.0008274	1.412e-6
NEW	0.0009584	8.8306e-7

The equivalent elastic strain of Existing and New design defines the maximum and minimum strain of disc brake rotor.

Table 4. Equivalent stress von mises stress of existing and new design

DESIGN	MAX. STRESS	MIN. STRESS
EXISTING	8.8406e7	1.1481e5
NEW	1.6187e8	9.7137e4

The maximum distortion energy of existing and new design shows maximum and minimum stress.

V. CONCLUSION

In this project disc brake rotor with vertical hole on the thickness region was designed by using CATIA modelling software. Thermal analysis was carried out on ANSYS simulation software in order to predict the thermal deformation and total heat flux established in the disc. Crack development reduction was achieved by generating hole on inner surface of disc which was allowing atmospheric air and reducing the thermal stress.

Here new design safety factor was proven by Ansys structural analysis. The comparison was made between existing design and new design results was obtained from FEM was done and all the values obtained from the analysis are less than their allowable values. Hence best suitable design, disc is suggested based on the performance.

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