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THERMAL BEHAVIOR OF DISC BRAKE ROTOR USING FINITE ELEMENT ANALYSIS

Mr. Deepak Kumar Sahu[1], Mrs. Poonam Diwan[2]

[1]*M. Tech Scholar, Department of Mechanical Engineering, VEC Lakhanpur, C.G. - India*
[2]*Assistant Professor, Department of Mechanical Engineering, VEC Lakhanpur, C.G. - India*

Abstract - *A brake is a mechanical device which slowing or stopping a moving object or preventing its motion. A disk brake consists of a cast iron disc bolted to the wheel hub and a stationary housing called caliper. The caliper is connected to some stationary half of the vehicle just like the shaft casing or the stub shaft as is forged in two components every part containing a piston. There is one most crucial system in the vehicle that is brake systems. Without brake in the vehicle can place a traveller in unsafe position. Disc brakes area unit exposed to giant thermal stresses throughout routine braking and extraordinary thermal stresses throughout exhausting braking. The aim of the project is to identify the thermal behavior of disc brake and create a model of brake plate which configuration is secure passionate about Thermal circulation using solid works.*

***Key Words*: FEA (Finite element analysis), DoF (Degree of Freedom),**

1. INTRODUCTION

This paper shows thermal-structural analysis of a disc brake rotor with hole for ventilation. In paper thermal-structural analysis of a disc brake rotor using the FFE- Plus problem Solver. The FFE-Plus solver uses advanced matrix reordering techniques that makes it more efficient for large problems. In general, FFE-Plus is faster in solving large problems and it becomes more efficient as the problem gets larger. The investigation of thermal behavior of disc brake rotor with gray cast iron, the thermal distribution of disc rotor is generated in solid works simulation. This work deals with the thermal analysis of disc brake of a vehicle using FEA. Repetitive braking of the vehicle results in heat generation throughout every braking event. The main purpose of this study is to analysis the thermal behavior of the brake disc during the braking phase. Heat generation and dissipation of disc brake are analyzed. The objective of this work is to investigate and analyze the temperature distribution of rotor disc during operation using FFE-Plus solver.

In these Disc Brake design, the thermal expansion is considered to be one of the main contributors for the failure of the disc brake. In this paper, thermal behavior is measured by using analytical method as well as Finite element analysis. Solid Works 2017 software is used to generate the 3-D solid model of disc brake. SolidWorks Simulation software package is used to analyze the heat flux.

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2. MATERIAL PROPERTY

For disc brake basic materials used range from steel, cast iron and different hard materials. Cast iron is used for this analysis, which have sufficient harden ability. The Cast Iron contains greater than 2% of carbon.

Table-1: Thermal Properties of Cast Iron

Material properties	Cast iron
Thermal conductivity ($w/m.\ k$)	46
Density($g/cm3$)	7.2
Specific heat (J/kg.k)	380
Thermal expansion($\mu m/mk$)	11
Elastic modulus (GPa)	110
Coefficient of friction (µ)	0.4

Table -2: Material Property

Elastic Modulus	66178.1	N/mm^2
Poisson's Ratio	0.27	-
Shear Modulus	50000	N/mm^2
Mass Density	7200	kg/m^3
Tensile Strength	151.658	N/mm^2
Compressive Strength	572.165	N/mm^2
Thermal Expansion Coefficient	1.2e-005	/K
Thermal Conductivity	45	W/(m·K)
Specific Heat	510	J/(kg·K)

It is group of iron-carbon alloys. Carbon (C) is 2% to 4%. Silicon (Si) is 1% to 3%. It is also contain manganese and some impurities like sulfur and phosphorus. The other designation of this material is shown in Table-2.

3. SOLID MODELING OF BRAKE ROTOR

This is part modelling of Disc brake rotor in SolidWorks. In this project showing Effie a simulation by using Simulation parameter of a brake rotor from the SolidWorks. It will cover the setup and running of a thermal analysis as well as the post-processing of these results. The final results of this study can be seen here with visual represents the temperature distribution on the rotor after braking. Insert reference geometry and for construction of geometry, I was select the right plane and the top plan. Sketch a circle with the Sims and the origin and give this circle a dimension. So except now go to features and choose extruded boss now in the start condition choose offset and give it an offset of 2.5mm. Thereafter click this face and start a new sketch press control one to view from the front plane and select your circle tool sketch your circle with the sins in the origin and give the circle a dimension.

Figure- 1: Solid Model of Disc Rotor

Most leading vehicle makers suggest brake disc skimming (US: turning) as a solution for lateral run-out, vibration issues, and brake noises. The machining method is performed during a brake shaper, which removes a very thin layer off the disc surface to clean off minor damage and restore uniform thickness. Machining the disc as necessary can maximize the mileage out of the present discs on the vehicle. Braking systems accept friction to bring the vehicle to a halt – hydraulic pressure pushes restraint against a forged iron disc or brake shoes against the inside of a cast iron drum. When a vehicle is decelerated, the load is transferred to the front wheels – this means that the front brakes do most of the work in stopping the vehicle.

4. MESHING OF BRAKE ROTOR

One of the final steps is to create the mesh for the study. The mesh breaks down the entire model into smaller elements to be analysed. Right-click mesh under the simulation study and select create mesh for the rotor a curvature base. Mesh is most appropriate and can be set under mesh parameters.

Table -3: Mesh Details

Study name	Thermal behavior
Mesh Type	Solid Mesh
Mesher Used	Curvature-Based mesh
Jacobian point	4 points
Max Element Size	1.38079mm
Min Element Size	0.276157mm
Mesh Quality	High
Total Nodes	1176974
Total Element	758491
Maximum Aspect Ratio	10.422
Percentage of element with aspect ratio < 3	99.5
Percentage of element with aspect ratio > 10	0.000132
% of distorted element(Jacobian)	0

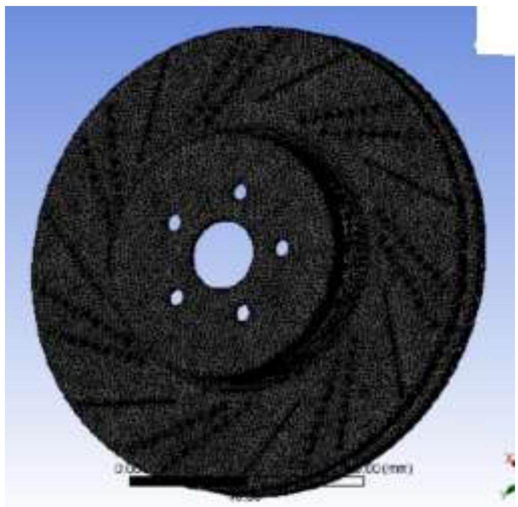

Figure- 2: Meshing of Disc Rotor

Any of these parameters can be changed based on how precise the study will be however the more elements there are. In this study the longer the study will take to run once the mesh is created. The study can now be run by selecting run under the simulation lab, once the study has been run the temperature distribution will be shown on the rotor. The units as well as the type of plot can be changed by right-clicking the thermal result plot and selecting edit definition for the processing can be done such as using the probe tool in viewing the temperature of one area over the entire timeframe.

5. CALCULATION FOR INPUT PARAMETERS

The rotor model heat flux is calculated for the Disc brake moving with a velocity 41.67 m/s (150kmph) and the following is the calculation.

Fd = Force on the disc
Rt = Radius of tire
Rr = Radius of rotor
R2 = Outer Radius of the pad
R1 = Inner Radius of the pad
ts = time taken to stop the automobile
v = initial speed
v = $\sqrt{\mu g d}$ = m/s

Stopping distance = $\frac{V^2}{2a}\,m$

Rotational Speed (ω) = $\frac{v}{Rt}$ rad/sec

Mass of vehicle (m) = 180kg
Final velocity (u) = 150 km/h = 41.67 m/s
Initial velocity (v) = 0 m/s
Brake rotor dia. = 0.17454m
Axle weight distribution (γ) = 0.35
Kinetic energy absorbed by disc (f) = 91%
Acceleration due to gravity (g) = 9.81 $N/m2$
Coefficient of friction = (μ) 0.4
Convection coefficient = 90 W/m^2
Bulk ambient temperature = 293 Kelvin
Kinetic energy defined by equation

1) Kinetic energy = $f\,\frac{1}{2}\,y\,\frac{m(u-v)^2}{2}$

$= 0.91 \times \frac{1}{2} \times 0.35 \times \frac{180(41.67-0)^2}{2}$ = 24886.793J

2) Stopping distance(x) = $\frac{u^2}{2\mu g} = \frac{41.67^2}{2\times0.4\times9.81}$ = 221.252m

3) Deceleration time = $v = u + at \rightarrow t = 4.09sec.$

4) Braking power (p_b) = $\frac{KE}{t} = \frac{24886.793}{4.09}$ = 6084.79W

5) Heat flux (Q) = $\frac{pb}{A} = \frac{6084.79}{0.04}$ = 152119.75W/m^2

The braking torque for the wheels is 60:35, So braking efficiency for rear wheel as 35%

Hence total heat flux = 0.35 × 152119.75= 53241.91W/m^2

The boundary conditions for thermal analysis of brake disc is shown is table 4.

Table -4: Boundary Condition

Braking power	6084.79W
Heat flux	53241.91$W/m2$
Heat transfer coefficient for cast iron	25015.26 $W/m2$°C
Ambient temperature	15°C

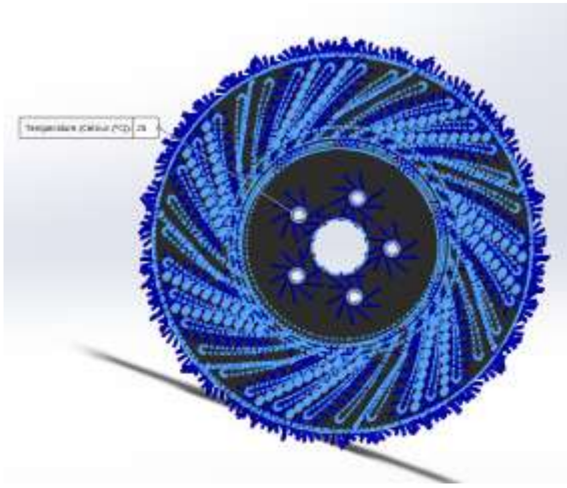

Figure- 3: Temperature in Disc Rotor

Table -5: Temperature Parameter

Study Name	Thermal Behavior of brake rotor
Load Name	Temperature (25 Celsius)
Entities	1242 edge(s)
Value	25
Units	Celsius
Identifier	3

6. FINITE ELEMENT ANALYSIS

The investigation of thermal behavior of disc brake rotor with gray cast iron, the thermal distribution of disc rotor is generated in solid works simulation is -1.765e+002 Celsius as shown in fig. 4. On the other hand the stress developed into the disc rotor which also calculate by simulation. After applied brake power, the temperature is rise and distributed into whole rotor. The stress was generated on rotor is 3.098e+007 as shown in fig. 5.

It is very tough to precisely model the brake disc. In order to do so, the researchers are still going on to find out transient thermal behavior of disc brake during braking applications. There is invariably a requirement of some assumptions to model any complicated geometry. One makes these assumptions keeping in mind the difficulties involved in the theoretical calculation and the importance of the parameters that are taken and those which are ignored. In modeling, we have a tendency to always ignore the things that are of less importance and have very little impact on the analysis.

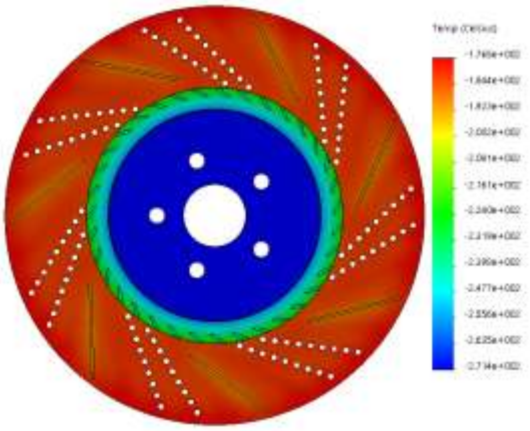

Figure- 4: Temperature Distribution in Disc Rotor

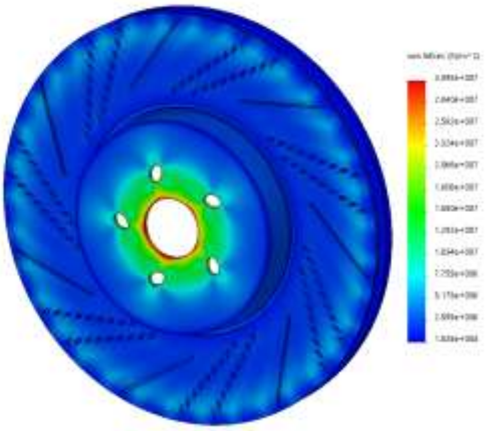

Figure- 5: Thermal Stress in Disc Rotor

The assumptions are perpetually created depending upon the main points and accuracy needed in modeling. Due to the appliance of brakes on the automotive disk brake rotor, heat generation takes place due to friction and this thermal flux has to be conducted and dispersed across the disc rotor cross-section. The condition of braking is extremely a lot of severe and so the thermal analysis must be carried out. The thermal loading further as the structure is axis-symmetric. Hence, axisymmetric analysis can be performed, but in this study, we performed a 3-D analysis, which is an exact representation for this thermal analysis. Thermal analysis is carried out and with the above load structural analysis is additionally performed for analyzing the stability of the structure.

7. RESULT AND CONCLUSION

The examination is finished exploitation FFE-Plus problem solver in SolidWorks, wherever FEA demonstrate simply includes of a plate, it's discovered that by different the distinctive consequences of temperature rise, redirection, and stress field received from the investigation. It demonstrates that in the vented disc with the forged iron decrease in temperature. Consequently, the brake plate configuration is secure passionate about Thermal circulation.

Table -6: Result From FEA

Experiment Name	Results	Unit
Thermal Distribution	1.765e+002	Celsius
Thermal Stress	3.098e+007	N/m²

All our Calculation, it's noted that there are some possible improvements related to disc brakes that can be done to further understand the effects of thermomechanical contact.

They are as follows:

(i) Tribology study of the disc —pads.

(ii) Study of dry contact sliding under the macroscopic aspect.

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BIOGRAPHIES

Mr. Deepak Kumar Sahu
M. Tech Scholar, Department of Mechanical Engineering, VEC Lakhanpur, C.G. – India

Mrs. Poonam Diwan
Assistant Professor, Department of Mechanical Engineering, VEC Lakhanpur, C.G. – India