International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 05 | May - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

THERMAL AND STATIC ANALYSIS OF AN AUTOMATED BRAKE SYSTEM USING CATIA

P.RAMANA BABU, S.SAI VAMSI, G.MANI KUMAR, M.B.S.ADITYA, K.GOWTHAM

Assistant Professor, Department of Mechanical Engineering, Avanthi institute of Engineering and Technology, Tamaram, Narsipatnam, Andhra Pradesh, India

U.G.Student, Department of Mechanical Engineering, Avanthi institute of Engineering and Technology, Tamaram, Narsipatnam, Andhra Pradesh, India

U.G.Student, Department of Mechanical Engineering, Avanthi institute of Engineering and Technology, Tamaram, Narsipatnam, Andhra Pradesh, India

U.G.Student, Department of Mechanical Engineering, Avanthi institute of Engineering and Technology, Tamaram, Narsipatnam, Andhra Pradesh, India

U.G.Student, Department of Mechanical Engineering, Avanthi institute of Engineering and Technology, Tamaram, Narsipatnam, Andhra Pradesh, India

ABSTRACT: Safety aspect in automotive engineering has been considered as a number one priority in development of new vehicle. Each single system in brake system has been studied and developed in order to meet safety requirement. Instead of having air bag, good suspension systems, good handling and safe cornering, there is one most critical system in the vehicle which is the braking systems.
If there is no proper braking system in the vehicle the passenger in the vehicle is in unsafe position. Therefore, it is a must for all vehicles to have proper braking system. Due to critical system in the vehicle, many of researchers have conducted a study on brake system and its entire component. In this project, we have conducted a study on performance of normal disc brake rotor of normal passenger vehicle at different speeds when different materials are used. The study is more likely concern of Stress distribution on disc brake rotor and deformation and stresses developed on it due to different speeds. The widely used brake rotor material is cast iron which consumes much fuel due to its high specific gravity. The aim of this project is to select the optimum material for the application of brake disc system emphasizing on the substitution of this cast iron by any other lightweight material.
The present project is aimed to study the given disc brake rotor for its stability and rigidity, for this Thermal analysis and coupled structural analysis is carried out on a given disc brake rotor to find out its deformation, stress when different materials are used. For these three different materials in each case is analyzed.

KEYWORDS: Disc brake, Disc brake rotor, CATIA, ANSYS

INTRODUCTION

Brakes are most important safety parts in the vehicles. Generally all of the vehicles have their own safety devices to stop their car. Brakes function to slow and stop the rotation of the wheel. To stop the wheel, braking pads are forced mechanically against the rotor disc on both surfaces. They are compulsory for all of the modern vehicles and the safe operation of vehicles. In short, brakes transform the kinetic energy of the car into heat energy, thus slowing its speed.
Brakes have been retuned and improved ever since their invention. The increases in travelling speeds as well as the growing weights of cars have made these improvements essential. The faster a car goes and the heavier it is, the harder it is to stop. An effective braking system is needed to accomplish this task with challenging term where material need to be lighter than before and performance of the brakes must be improved. Today's cars often use a combination of disc brakes and drum brakes. For normal sedan car, normally disc brakes are located on the front two wheels and drum brakes on the back two wheels. Clearly shows that, together with the steering components and tires represent the most important accident avoidance systems present on a motor vehicle which must reliably operate under various conditions.
However, the effectiveness of braking system depends on the design itself and also the right selection of material. In order to understand the behaviors of braking system, there are three functions that must be complied for all the time.

a) The braking system must be decelerate a vehicle in a controlled and repeatable fashion and when appropriate cause the vehicle to stop.
b) The braking should permit the vehicle to maintain a constant speed when traveling downhill.
c) The braking system must hold the vehicle stationary when on the flat or on gradient.

I. RELATED WORK

The present project entitled "Thermal and structural analysis of disc brake rotor" is developed with lot of study done over many of the reputed international journals. The present project is based on the journal "Transient Thermal and Structural Analysis of the Rotor Disc of Disc Brake" by V.M.M.Thilak , R.Krishnaraj, Dr.M.Sakthivel, K.Kanthavel, DeepanMarudachalam M.G, R.Palani.The input parameters for generation of the temperature and the stress distribution along the brake disc is analyzed in the ANSYS are taken from the journal "Simulation of Temperature Distribution in Brake Discs" by KhongKengLeng and the official Wikipedia of Google.

The sources for the basic design specifications are taken from the official site of the 'MARUTHI SUZUKI'. For the completion of the project the basic fundamental chapters are documented with the aid of websites of Google.Thus completing the project under proper assistance.

A literature review was conducted to investigate the past research that has been done in many areas related to this work.

II. METHODOLOGY

Begin with a literature review, a lot of papers and journal has been read up and a part of it has been considered in this project. Later, the precise dimensions have been used to develop a 3D drawing by using CATIA.

In the second stage, thermal analysis has been done where the heat flux has been calculated. Heat flux is calculated based on kinetic energy processed by the rotor rotating at a speed of 60kmph and 120kmph of a normal passenger vehicle. Later, value of heat flux and temperature has been applied on finite element analysis and temperature distribution

Next, the fractional 3D model of disc brake rotor has been transfer to finite element software which is ANSYS. Thermal analysis has been done on transient state and static structural analysis has done. Assigning material properties, angular velocity to the meshing model has been done in this stage. Then, completed meshing model has been submitted for analysis. Finally deformation, stresses developed at that speed. Same procedure has been adopted for different materials. Tabulating all the results obtained and better material is proposed.

Material	Thermal Conductivity (w/m k)	Co-Efficient Of Thermal Conductivity	Young's Modulus (Gpa)	Density (Kg/m$^{2)}$
C.I	46.33	$10.4x10^{-6}$	170	7200
Fc250	54.34	$1.33x10^{-5}$	113	7200
Almmc	159	$6.5x10^{-6}$	107	3200
S2glass	1.45	$1.6x10^{-6}$	86.9	2490

Table.1 Properties of Materials

III. CAD MODELLING

General Modeling Process for Each Part:

a) Plan the part
b) Create the base feature
c) Create the remaining features
d) Analyze the part
e) Modify the features as necessaries
f) Assembly modeling

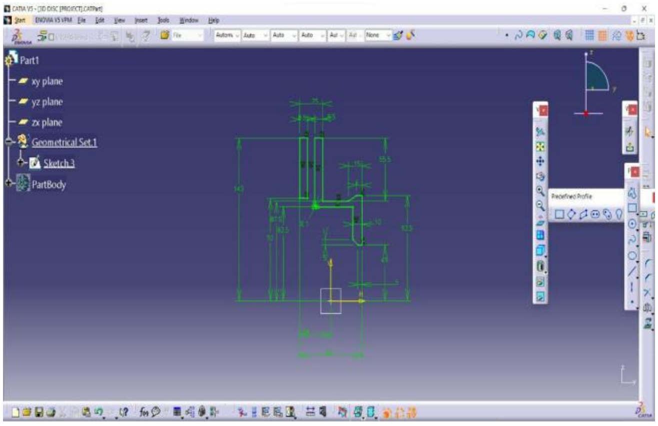
Assemblies can be created from parts, either combined individually or grouped in subassemblies. The CATIA V5 builds these individual parts and subassemblies into an assembly in a hierarchical manner according to relationships defined constrains. As in part modeling, the parametric relationship allows you to quickly update an entire assembly based on a change in one of its parts.

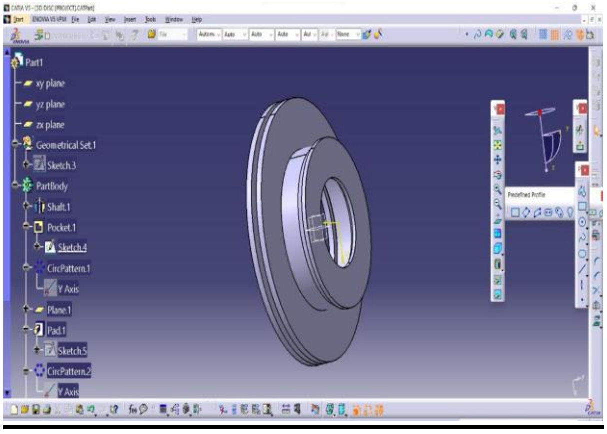
The general process for assemblies and subassemblies is similar to that of building parts:

a) Lay out the assembly
b) Create the base part
c) Create and attach the remaining parts
d) Analyze the assembly
e) Modify the assembly as necessary

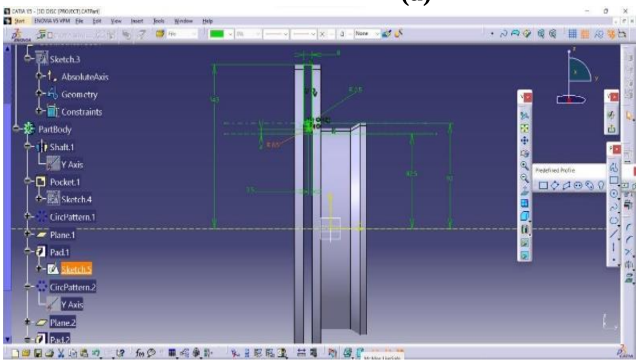
Fig1: Catia Modelling (a) 2D Sketch(1) with Dimension (b) Applying a shaft command (c) Create a plane of type angle/normal to plane with below specifications and draw the sketch(2) (d) Create a plane of type angle/normal to plane with below specifications and draw a sketch(3) (e) The 3D Model Object

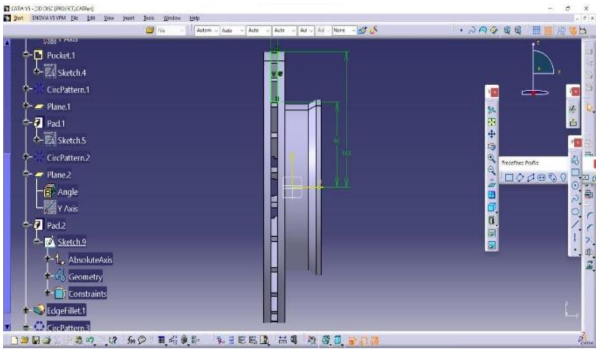
International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 05 | May - 2024 SJIF Rating: 8.448 ISSN: 2582-3930



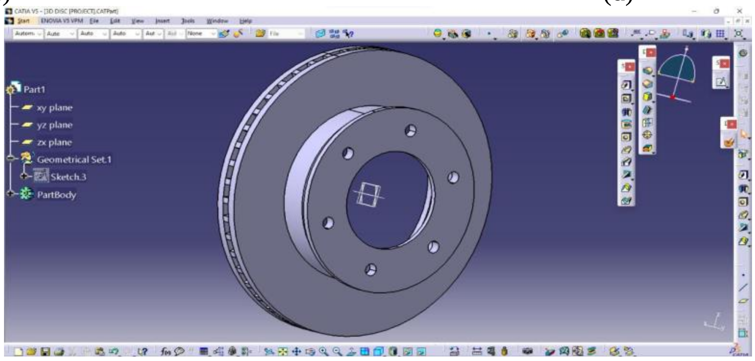


(a) **(b)**





(c) (d)



(e)

IV. ANALYSIS AND RESULTS

ANSYS

A static analysis can be either linear or non-linear. In this work we have considered nonlinear transient analysis.

The procedure for ANSYS analysis consists of three main steps:

a) Build the model.
b) Obtain the solution.
c) Review the results.

STEPS INVOLVED IN ANSYS:

In general, a finite element solution can be broken into the following these categories.

1. Preprocessing module: Defining the problem. The major steps in preprocessing are given below

a) Defining key points /lines/areas/volumes
b) Define element type and material /geometric /properties
c) Mesh lines/areas/volumes/are required

The amount of detail required will depend on the dimensionality of the analysis (i.e. 1D, 2D, axis, symmetric)

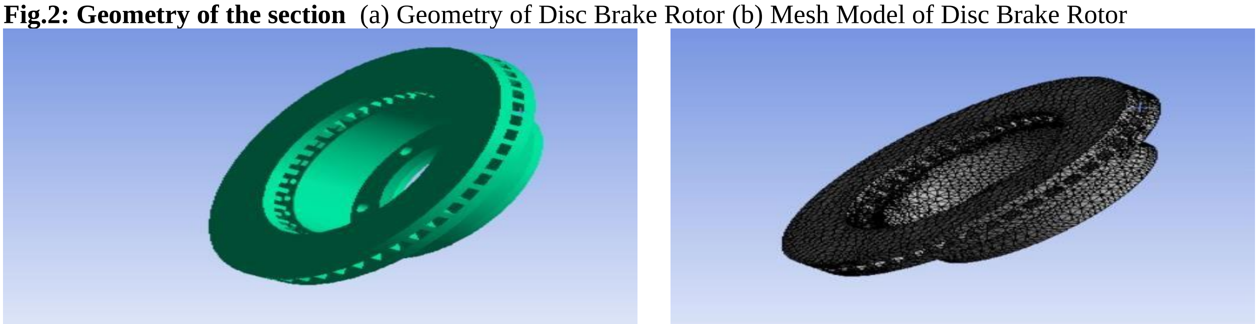
International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 05 | May - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

2. Solution processor module: assigning the loads, constraints and solving. Here we specify the loads (point or pressure), constraints (translation, rotational) and finally solve the resulting set of equations.
3. Post processing module: further processing and viewing of results In this stage we can see:

a) List of nodal displacement
b) Elements forces and moments
c) Deflection plots
d) Stress contour diagrams

Geometry of the section:
Outer diameter of the disc = 286 mm
Inner diameter of the disc = 175 mm
Thickness of disc =25 mm

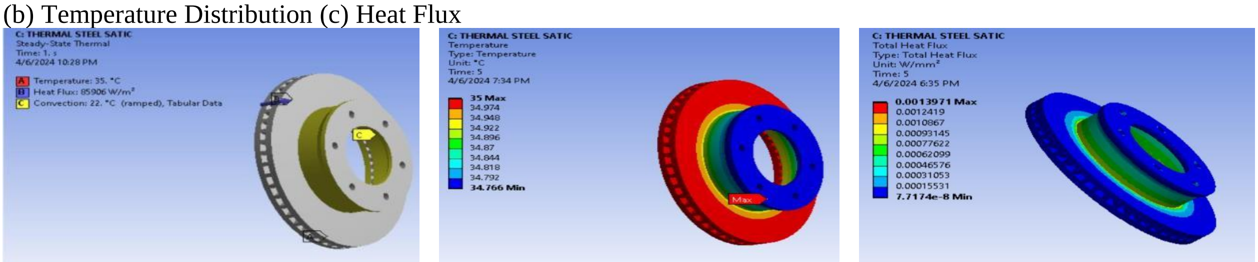
Fig.2: Geometry of the section (a) Geometry of Disc Brake Rotor (b) Mesh Model of Disc Brake Rotor



(a) (b)

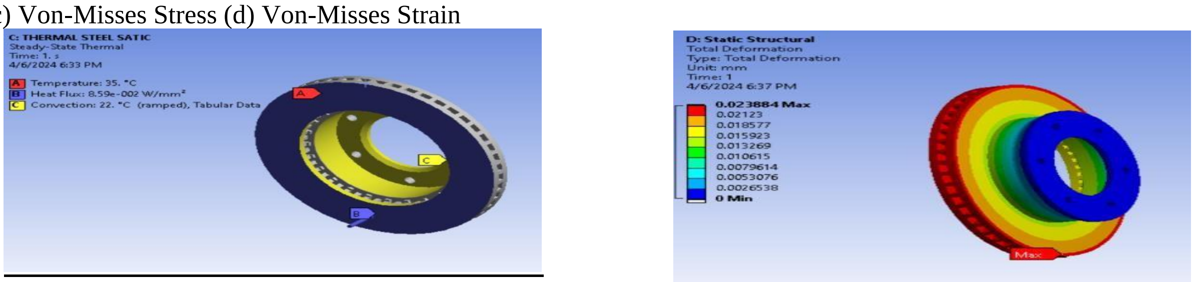
For CAST IRON(CI):

Fig.3: Static Thermal Conditions at 60Kmph (a) Load & Boundary Condition for Static Thermal Analysis (b) Temperature Distribution (c) Heat Flux

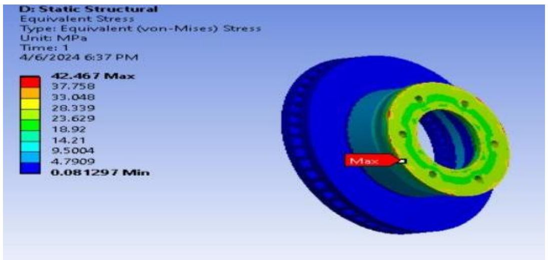


(a) (b) (c)

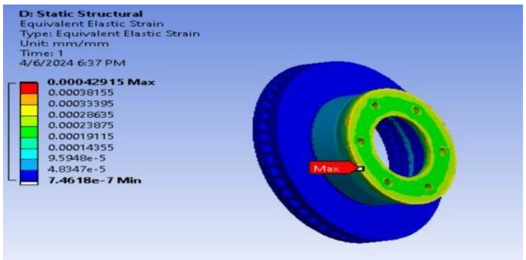
Fig.4: Static Structural Conditions at 60Kmph (a) Load & Boundary Condition for Static Structural (b) Deformation (c) Von-Misses Stress (d) Von-Misses Strain



(a) (b)

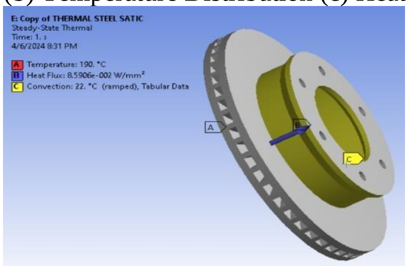


(c)

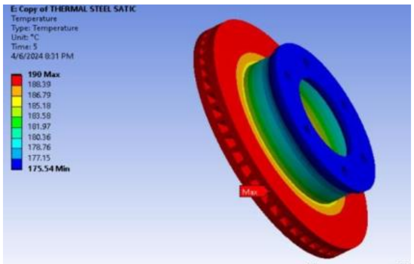


(d)

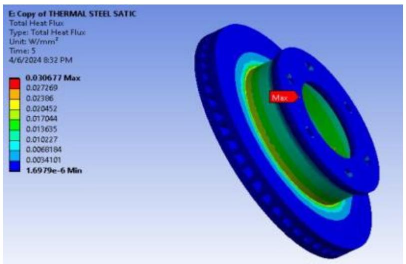
Fig.5: Static Thermal Conditions at 120Kmph (a) Load & Boundary Condition for Static Thermal Analysis (b) Temperature Distribution (c) Heat Flux



(a)

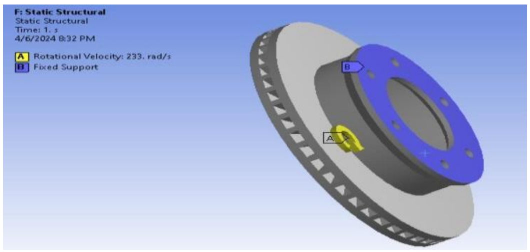


(b)

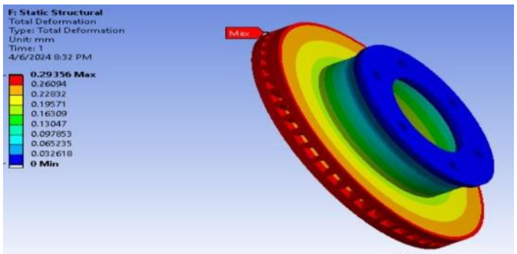


(c)

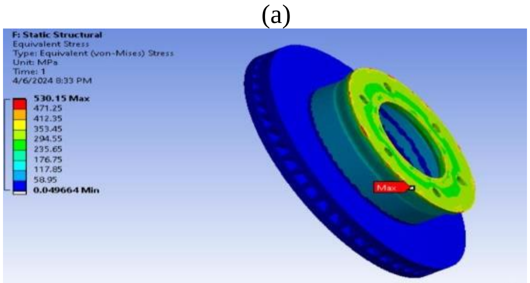
Fig.6: Static Structural Conditions at 120Kmph (a) Load & Boundary Condition for Static Structural (b) Deformation (c) Von-Misses Stress (d) Von-Misses Strain



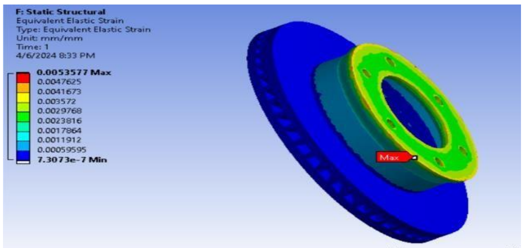
(a)



(b)



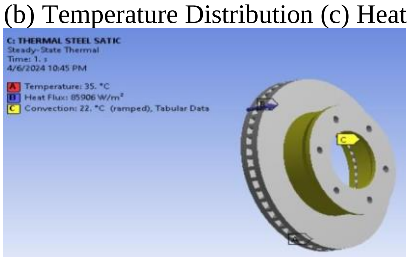
(c)



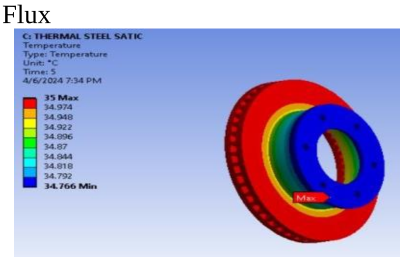
(d)

For ALUMIUM-SIC:

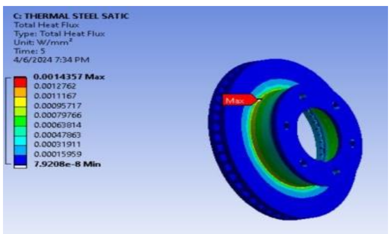
Fig.7: Static Thermal Conditions at 60Kmph (a) Load & Boundary Condition for Static Thermal Analysis (b) Temperature Distribution (c) Heat Flux



(a)



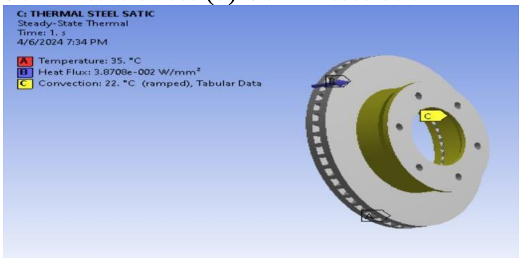
(b)



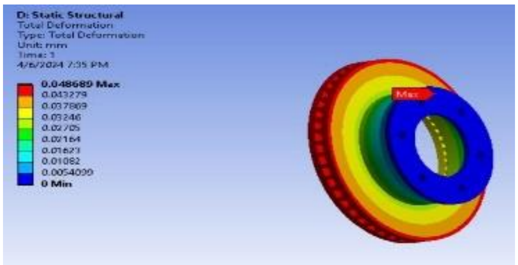
(c)

Volume: 08 Issue: 05 | May - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

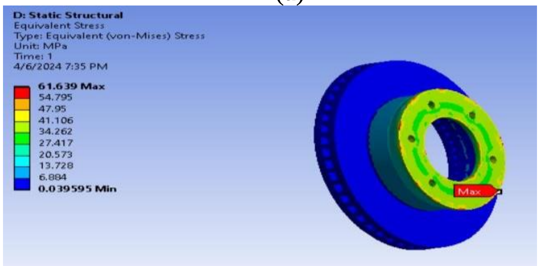
Fig.8: Static Structural Conditions at 60Kmph (a) Load & Boundary Condition for Static Structural (b) Deformation (c) Von-Misses Stress (d) Von-Misses Strain



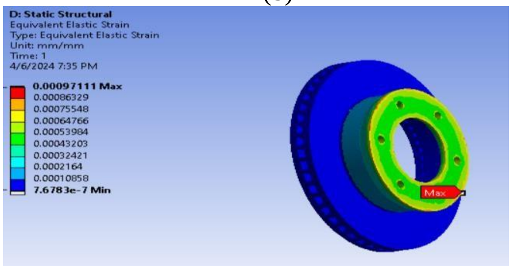
(a)



(b)

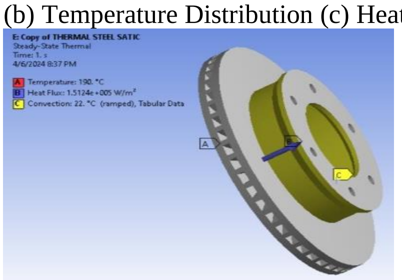


(c)

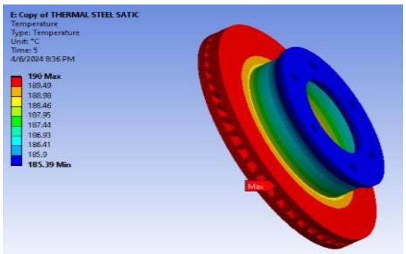


(d)

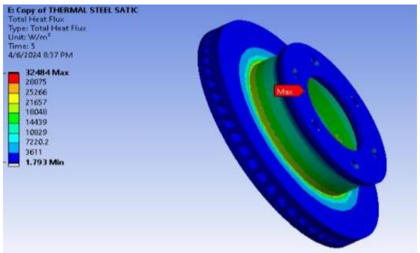
Fig.9: Static Thermal Conditions at 120Kmph (a) Load & Boundary Condition for Static Thermal Analysis (b) Temperature Distribution (c) Heat Flux



(a)

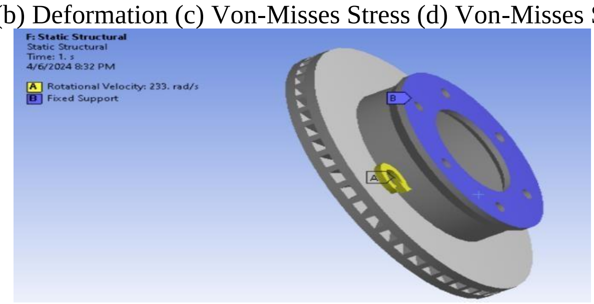


(b)

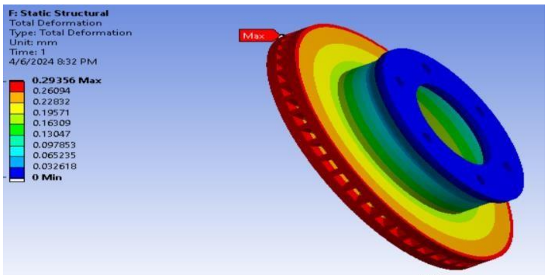


(c)

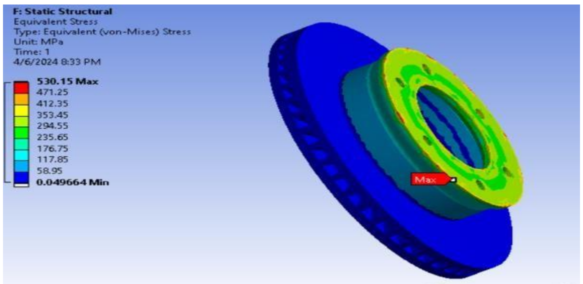
Fig.10: Static Structural Conditions at 120Kmph (a) Load & Boundary Condition for Static Structural (b) Deformation (c) Von-Misses Stress (d) Von-Misses Strain



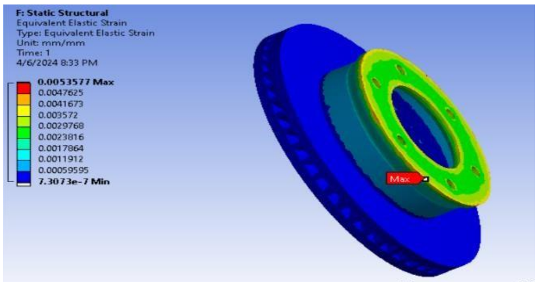
(a)



(b)



(c)



(d)

CASE STUDIES:

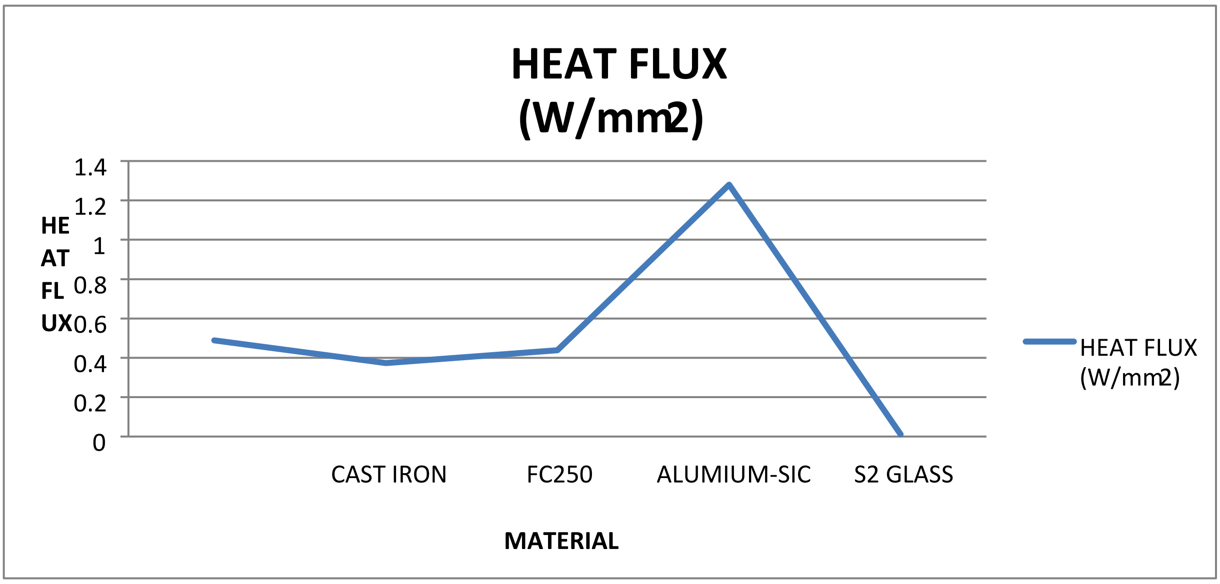
CASE STUDY FOR 60 KMPH						
S.NO.	**MATERIAL**	**TEMPERATURE (oC)**	**HEAT FLUX (W/mm2)**	**DEFORMATION (mm)**	**STRESS (MPA)**	**STRAIN (MM/MM)**
1	CAST IRON	35.024	0.374	0.015	28.57	$2.50\ e^{-4}$
2	FC250	35.024	0.438	0.019	33.24	$2.00\ e^{-4}$
3	ALUMIUM-SIC	35.024	1.28	0.009	13.25	$1.20\ e^{-4}$
4	S2 GLASS	35.024	0.011	0.0012	2.83	$3.26\ e^{-5}$

Table.2 Case Study for 60Kmph

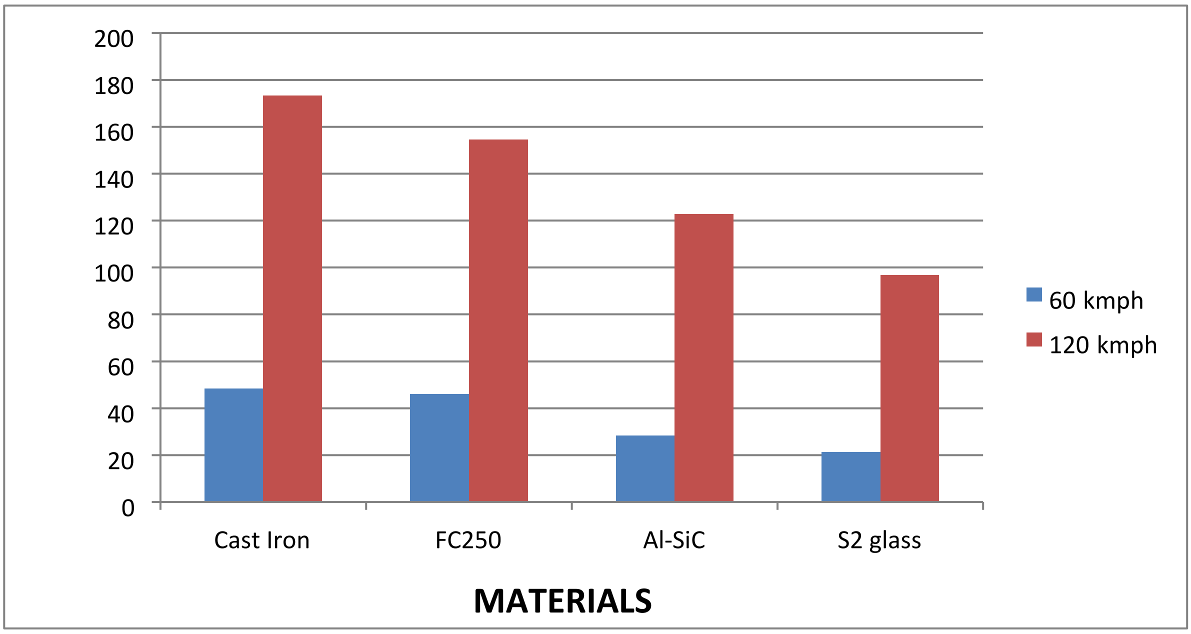
CASE STUDY FOR 120 KMPH						
S.NO.	**MATERIAL**	**TEMPERATURE (oC)**	**HEAT FLUX (W/mm2)**	**DEFORMATION (mm)**	**STRESS (MPA)**	**STRAIN (MM/MM)**
1	CAST IRON	218.51	4.73	0.128	338.71	$1.90\ e^{-3}$
2	FC250	218.51	5.55	0.165	288.87	$2.50\ e^{-3}$
3	ALUMIUM-SIC	218.51	16.24	0.08	133.63	$1.20\ e^{-3}$
4	S2 GLASS	218.51	0.14	0.021	27.85	$3.20\ e^{-4}$

Table.3 Case Study for 120Kmph

COMPARATIVE RESULTS:



Graph.1 Variation of Heat Flux in W/mm2 for Different Materials



Graph.2 Variation of Stress in MPa for Different Materials at Different Speeds

CONCLUSION

In our project thermal analysis coupled with structural analysis of disc brake rotor has been done.Our project mainly concerned with temperature distribution, deformation, stress that are developed on the disc brake rotor rotating at different speeds when different materials are used. The different materials used are cast iron, CAST IRON (CI), Al-SiC mmc, S2 glass. Present material used for disc brake is cast iron. we are replacing the present material with another three materials, since their density is less when compared to cast iron thereby reducing the weight of the disc.

By observing stress values obtained from ANSYS at different speeds, it was found that S2 glass is the better material for disc brake rotor but as per cost point of view it is very high. So it is preferable for luxary cars only. Gray cast iron (FC 250) is a common material for disc brakes due to its thermal stability, damping capability, and cost-effectiveness. However, its weight and limitations under extreme conditions may lead to the preference for alternative materials. For economical cars disc brake rotors made of Al-SiC is preferred.

REFERENCES

1)Thermal and Structural Analysis of The Rotor Disc of Disc Brake - V.M.M. Thilak, R. Krishna Raj, Dr. M. Sakthivel, K. Kanthavel, Deepan Marudachalam M.G.R. Palani.

2)Material Selection Method in Design of Automotive Brake Disc -M.A. Maleque (Member, IAEN, S. Dyuti and M.M. Rahman (Member, IAENG).

3)Tribological Investigation of Titanium-Based Materials for Brakes -Peter J. Blau, Brian C. Jolly, Jun Qu, William H. Peter, Craig A. Blue Materials Science and Technology Division, Oak Ridge National Laboratory, TN, USA.

4)Simulation of Temperature Distribution in Brake Discs Submitted By: Khong Keng Leng.

5)Development of Disc Brake Rotors for Heavy- And Medium-Duty Trucks with High Thermal Fatigue Strength -Junichiro YAMABE Masami TAKAGI Toshiharu MATSUI.

6)Numerical Simulation on Hardness Distribution for A CAST IRON (CI) Gray Cast Iron Brake Disc Casting and Its Experimental Verification -Chun-Ping Yeh, Weng-Sing Hwang, And Chienhen Lin Department of Materials Science and Engineering, National Cheng Kung University.

7)Thermal Performance Analysis and Geometrical Optimization of Automotive Brake Rotors by Zhongzhe Chi.

8)Thermal Engineering by Rajput.

9)Heat Transfer by R C Shachdev.

10)Design and Thermo-Structural Analysis of Automotive Disc Brake: Static thermal analysis to examine thermal variations across the disc during repeated brake applications using ANSYS.

11)Design and Thermomechanical Finite Element Analysis of Brake Disc: Numerical modeling using ANSYS to follow the evolution of global temperatures for full and ventilated brake discs during braking scenarios
12)Thermal–Mechanical Coupled Analysis of a Brake Disk Rotor: Analyzing temperature distribution, stresses, and deformation across the brake disk profile using ANSYS. Materials studied include Aluminum base metal matrix composite and High Strength Glass Fiber composites.
13)Thermomechanical Model for the Analysis of Disc Brake Using the Finite Element Method: Using ANSYS to analyze heat generation and dissipation in brake discs based on vehicle speed and other parameters.
14) K. S. S. Gurudatta, V. Harikiran, M. V. D. K. Raju, B. Rama Krishna & I. Jagadeesh"Design and CFD Analysis of Drone Thrust with Duct"https://doi.org/10.1007/978-3-031-15175-0_44 ,07 June 2023 ,pp 545–561