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MODELING AND ANALYSIS OF ROTOR BRAKES

Mrs. K. Anoosha[1]
Asst. Professor, Department Of Mechanical Engineering Guru Nanak Institute Of Technology Hyd,
Batthula Anil kumar[2]
M. Mahesh[3]
Thalamanchi Anil[4]
UG Student, Department Of Mechanical Engineering Guru Nanak Institute Of Technology Hyd (Telangana)

ABSTRACT
A Rotor disc brake is a type of brake that uses calipers to squeeze pairs of pads against a disc in order to create friction that retards the rotation of a shaft, such as a vehicle axle, either to reduce its rotational speed or to hold it stationary. The energy of motion is converted into waste heat which must be dispersed. Hydraulic disc brakes are the most commonly used form of brake for motor vehicles but the principles of a disc brake are applicable to almost any rotating shaft.

Keywords:
Rotor Brakes, Mechanical Modeling, Brake System Analysis, Finite Element Analysis (FEA), Thermal Performance.

INTRODUCTION

A rotor disc brake is a type of brake that uses calipers to squeeze pairs of pads against a disc in order to create friction that retards the rotation of a shaft, such as a vehicle axle, either to reduce its rotational speed or to hold it stationary. The energy of motion is converted into waste heat which must be dispersed. Hydraulic disc brakes are the most commonly used form of brake for motor vehicles but the principles of a disc brake are applicable to almost any rotating shaft.
Compared to drum brakes, disc brakes offer better stopping performance because the disc is more readily cooled. As a consequence, discs are less prone to the brake fade caused when brake components overheat. Disc brakes also recover more quickly from immersion (wet brakes are less effective than dry ones).

OBJECTIVES

- **Torque Capacity**: Achieve sufficient braking torque to decelerate or stop the rotor effectively.
- **Thermal Performance**: Design for optimal heat dissipation and thermal stability during braking.
- **Material Optimization**: Select materials with high thermal conductivity, wear resistance, and strength.
- **Structural Analysis**: Validate components under stress and fatigue loads to prevent deformation or failure.
- **Dynamic Stability**: Avoid oscillations, vibrations, or rotor instability during braking.
- **Weight and Space Constraints**: Minimize weight and size while maintaining performance, particularly in aerospace and automotive applications.
- **Noise and Vibration Control**: Address NVH (Noise, Vibration, and Harshness) concerns through damping and design refinement.
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ROLE OF ROTOR BRAKES IN AUTOMOBILES

- **Converting Kinetic Energy to Heat Energy**: The rotor (brake disc) works in tandem with brake pads to convert the vehicle's kinetic energy into heat through friction, slowing or stopping the vehicle.
- **Ensuring Vehicle Safety**: The rotor brake ensures safe deceleration during regular operation and emergency braking, preventing accidents.
- **Facilitating Smooth Deceleration**: Provides controlled and predictable braking to avoid abrupt stops, ensuring passenger comfort and reducing stress on vehicle components.

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- **Heat Dissipation**: The rotor's design (often with vents or grooves) helps dissipate the heat generated during braking, preventing brake fade and maintaining consistent performance.
- **Maintaining Stability**: The balanced design of brake rotors ensures even braking force distribution, maintaining vehicle stability and preventing skidding or loss of control.
- **Enhancing Performance**: High-performance vehicles use advanced rotor designs (e.g., drilled or slotted rotors) to improve braking efficiency, reduce weight, and enhance cooling.
- **Compatibility with Modern Systems**: Works with advanced technologies like ABS (Anti-lock Braking System), EBD (Electronic Brake force Distribution), and traction control systems for optimized braking under different conditions.
- **Durability and Longevity**: Designed to endure repeated braking cycles, ensuring reliability over the vehicle's lifespan.

METHODOLOGY

The methodology for modeling and analyzing rotor brakes involves several key steps: first, conducting a literature review to understand existing systems and identify gaps. Then, a physical model of the rotor brake system is developed, considering forces, friction, heat generation, and wear. Finite Element Analysis (FEA) or Computational Fluid Dynamics (CFD) simulations are used for stress, thermal, and dynamic analysis. Experimental testing is performed to validate the models, with data collected on braking performance, temperature, and wear. Finally, sensitivity and optimization analyses are carried out to refine the design, followed by a thorough results interpretation to improve the system's performance.

MODELLING ROTOR BRAKES

Rotor brake parts were modeled using **Catia v5 r20** for better analysis results of modelled key parts like the rotor, pads, caliper, and brackets. Modelled part used for the analysis under different conditions
Such as structural, thermal, contact, and dynamic analyses to assess performance, heat dissipation, and durability under braking conditions. This ensures optimized design for safety, reliability, and efficiency.

a) CATIA V5 R20:

CATIA V5 R20 is modelling tool widely used for modeling rotor brake parts due to its advanced capabilities. It allows detailed 3D modeling of components like the rotor, brake pads, calipers,

b) MODELING OF DISC BRAKES:

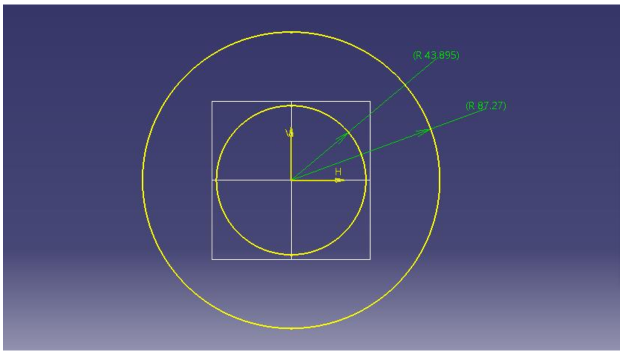

Fig 1: 2d sketch of pad

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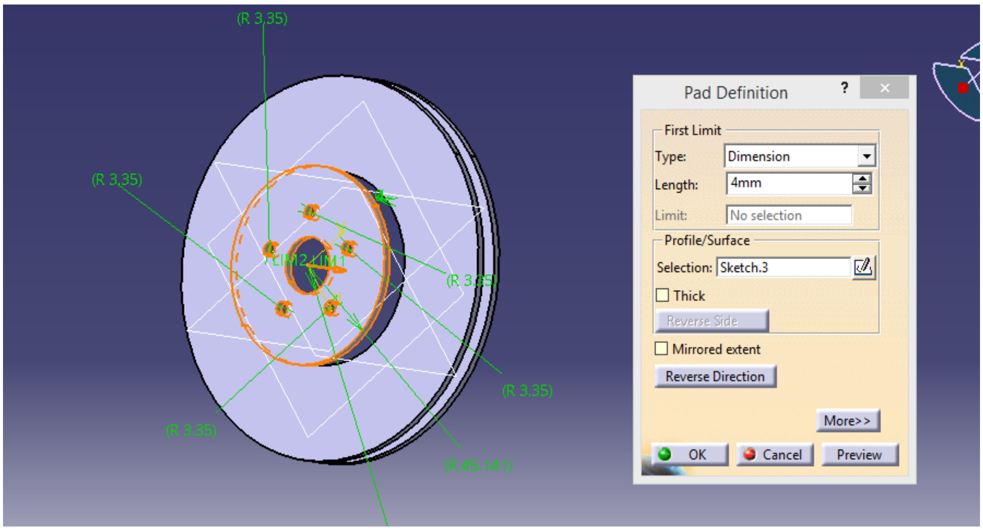

Fig 2: extrusion of feature with holes

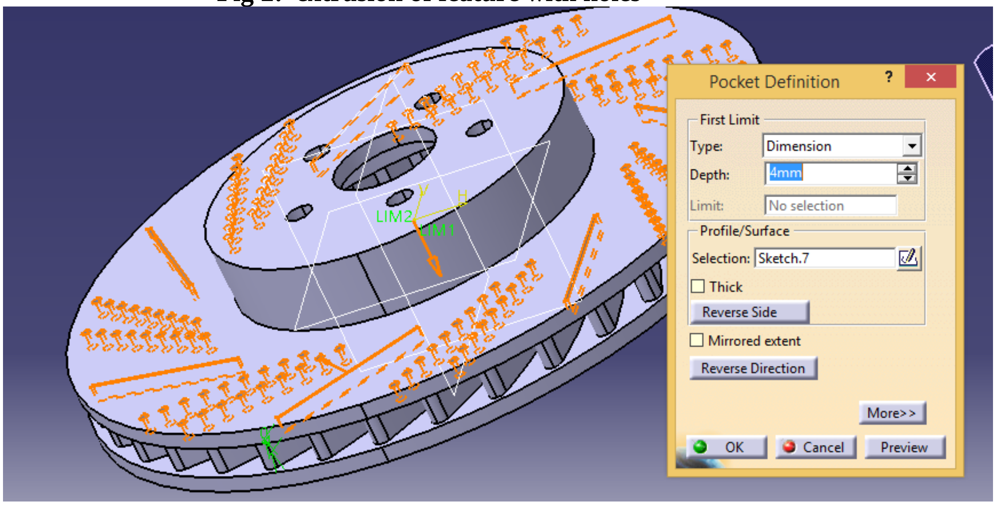

Fig 3: circular mirror of supporting spikes

c) MODELING OF CALIPER OF DISK BRAKE:

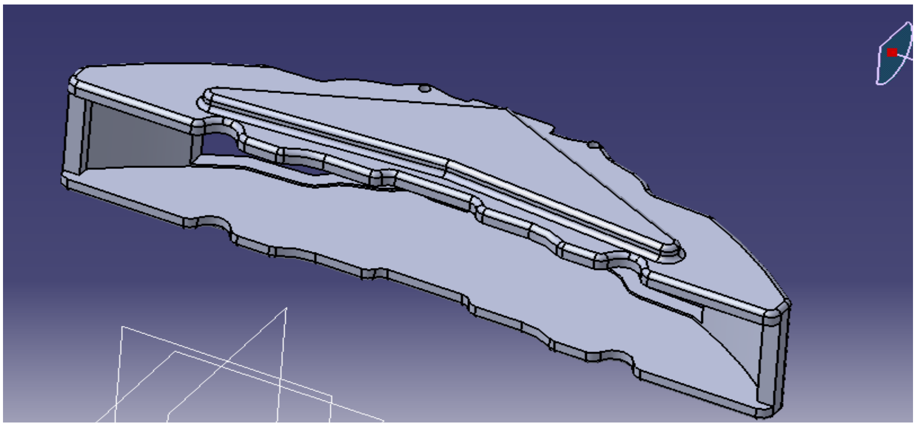

Fig 4: catia model of disk brake caliper

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d) ASSEMBLY OF DISK AND CALIPER:

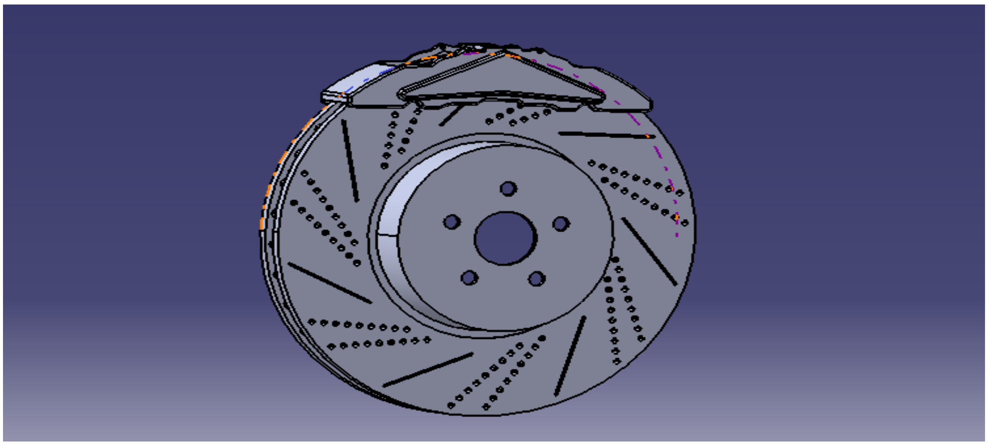

Fig 5: assembly disk brake caliper

e) DRAFTING OF ASSEMBLY:

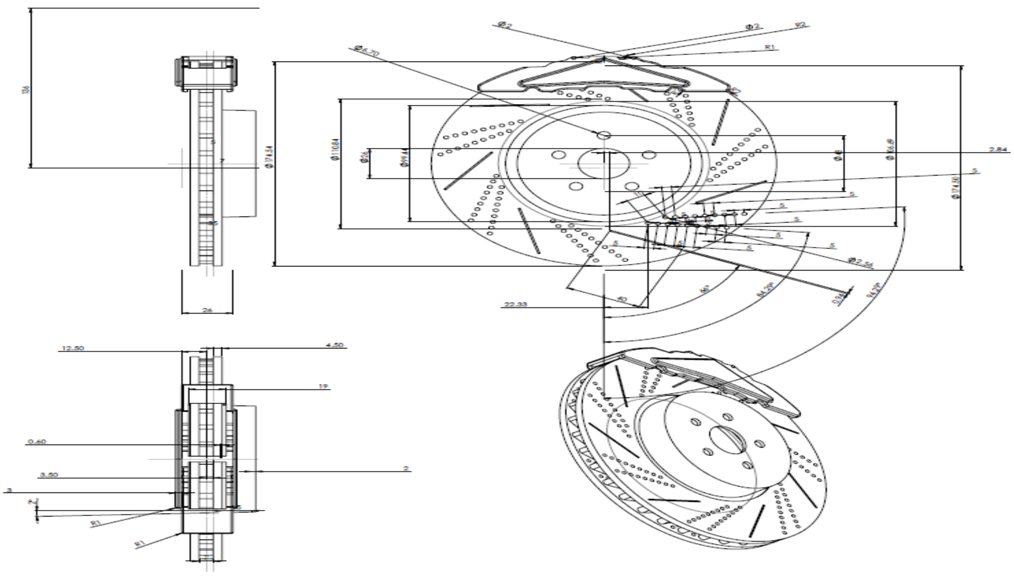

Fig 6: Orthographic projection of Assembly

V) ANALYSIS ROTOR BRAKES:

Rotor brake parts were modeled in **CATIA V5 R20** and analysis of key components like the rotor, pads, and caliper were done using the **ANSYS 16.0**, the Analysis of structural, thermal, contact, and dynamic analyses to assess performance, heat dissipation under braking conditions. This ensures the safety of the design under real time application and loading conditions.

A) STRUCTURAL ANALYSIS:

a) GENERATING MESH:

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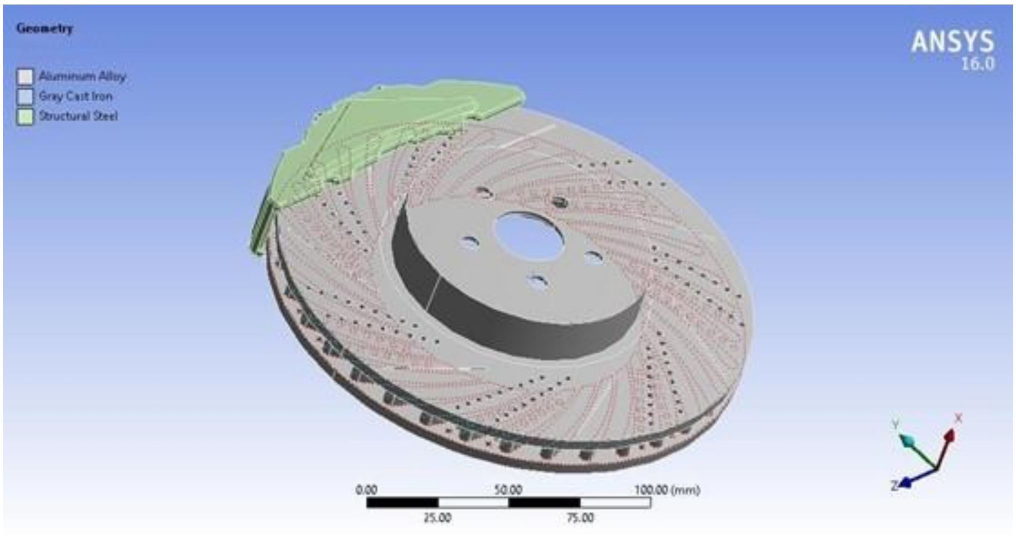

Fig 7: Imported part from Catia to Ansys

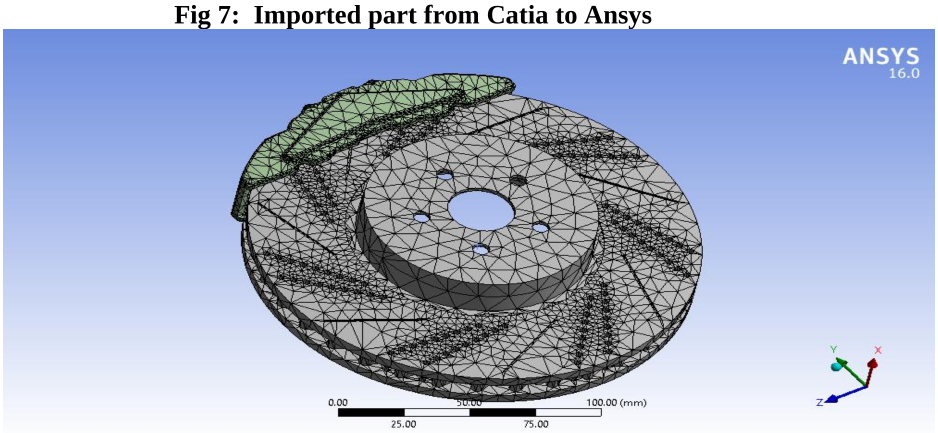

Fig 8: Mesh generating In Ansys

b) TOTAL DEFORMATION:

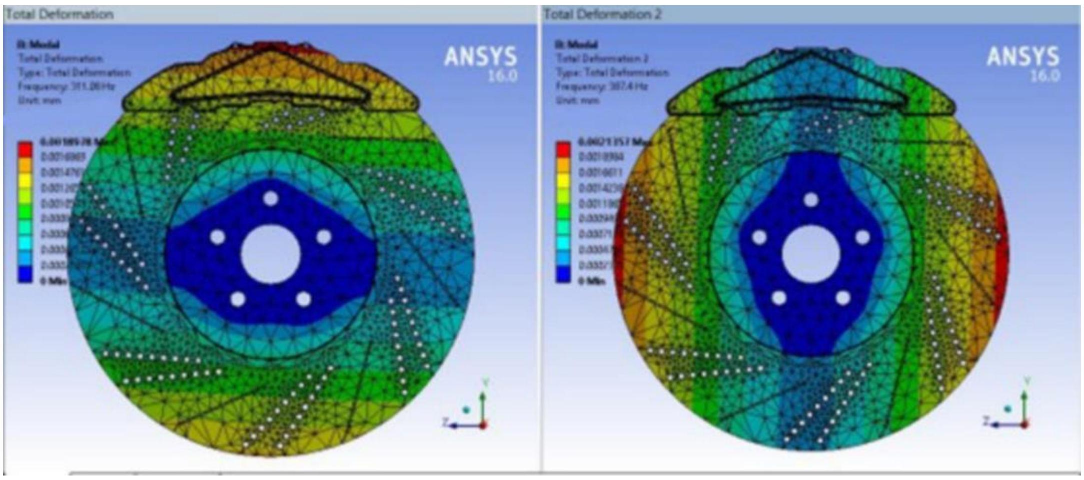

Fig 9: Total Deformation 1st and 2nd

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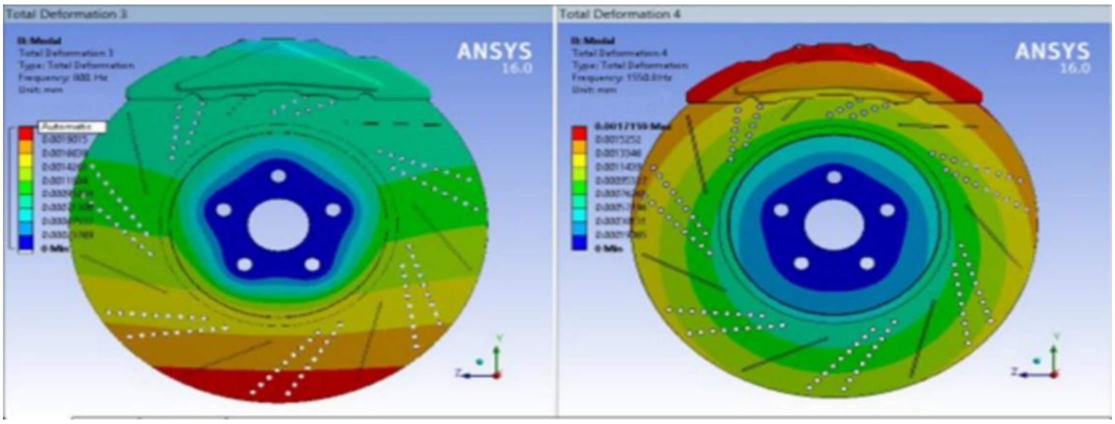

Fig 10: Total Deformation 3rd and 4t

d) STRUCTURAL ANALYSIS RESULTS:

Results	Minim...	Maximum	Units	Reported Frequency (Hz)
Total Deformation	0.	1.8978e-003	mm	311.08
Total Deformation 2	0.	2.1357e-003	mm	387.4
Total Deformation 3	0.	2.1392e-003	mm	800.
Total Deformation 4	0.	1.7159e-003	mm	1550.8
Total Deformation 5	0.	2.5111e-003	mm	1909.5
Total Deformation 6	0.	2.2572e-003	mm	1950.6

Results Summary from Ansys Workshop (Assembly)

B) THERMAL ANALYSIS:

Thermal Analysis is to find out the effect of temperature on the whole body of the model. Also, we will evaluate the total heat flux and the directional heat flux with respect to the direction heat flux with respect to axis.

a) RESULT SUMMARY FOR THERMAL ANALYSIS FROM ANSYS WORKBENCH

Results	Minimum	Maximum	Units	Time (s)
Temperature	51.608	100.72	°C	1.
Total Heat Flux	4.2174e-014	0.31535	W/mm²	1.
Temperature 2	96.661	100.08	°C	1.
Temperature 3	51.608	100.72	°C	1.
Total Heat Flux 2	3.0629e-005	1.9936e-002	W/mm²	1.
Total Heat Flux 3	8.1257e-005	0.31535	W/mm²	1.

RESULTS AND DISCUSSION

a) FOR MODAL ANALYSIS

S.no	Total deformation (mm)	Frequency (Hz)
1	0.00190	311.08
2	0.00214	387.4
3	0.00214	800
4	0.00172	1550.8
5	0.00251	1909.5
6	0.00226	1950.6

Table 1: Total Deformation Vs Frequency

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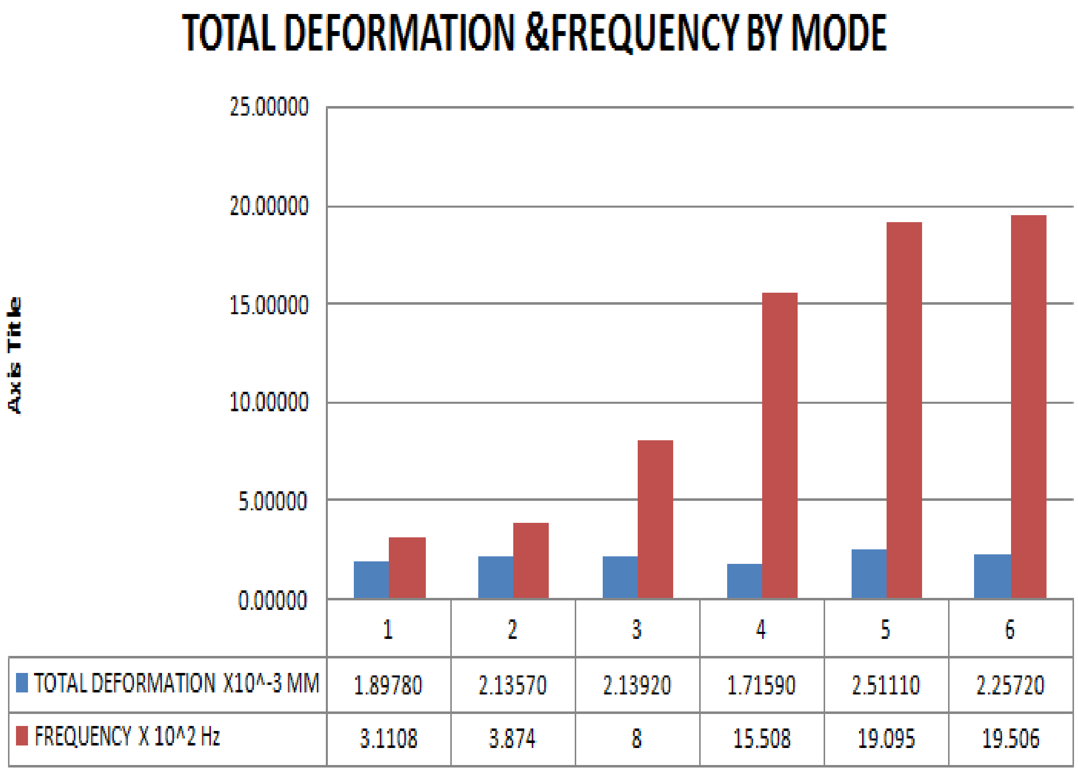

Graph 1: Total Deformation & Frequency by Mode

b) FOR STATIC ANALYSIS AT JOINT LOAD

S.no	Rotation Joint Load	Disc brake Total Deformation Mm	Caliper Total Deformation Mm	Disc brake Equivalent Stress Mpa	Caliper Equivalent Stress Mpa	Frictional Stress Mpa
1	1	1.5231	2.17e-12	7.86e-05	2.14e-07	2.44e-08
2	2	3.0463	2.80e-13	1.57e-04	4.05e-08	5.37e-08
3	3	4.5694	2.67e-13	2.36e-04	4.56e-08	8.71e-08
4	4	6.0926	3.59e-13	3.15e-04	4.84e-08	1.26e-07
5	5	7.6157	3.98e-13	3.93e-04	5.92e-08	1.40e-07
6	6	9.1389	3.59e-13	4.72e-04	5.41e-08	1.47e-07
7	7	10.662	3.90e-13	5.50e-04	5.46e-08	1.04e-07
8	8	12.185	3.32e-13	6.29e-04	5.15e-08	5.97e-08
9	9	13.708	3.49e-13	7.08e-04	6.39e-08	2.47e-08
10	10	15.231	3.34e-13	7.86e-04	6.29e-08	4.47e-08

Table 2: Resultant Deformations and Stress 1 To 10

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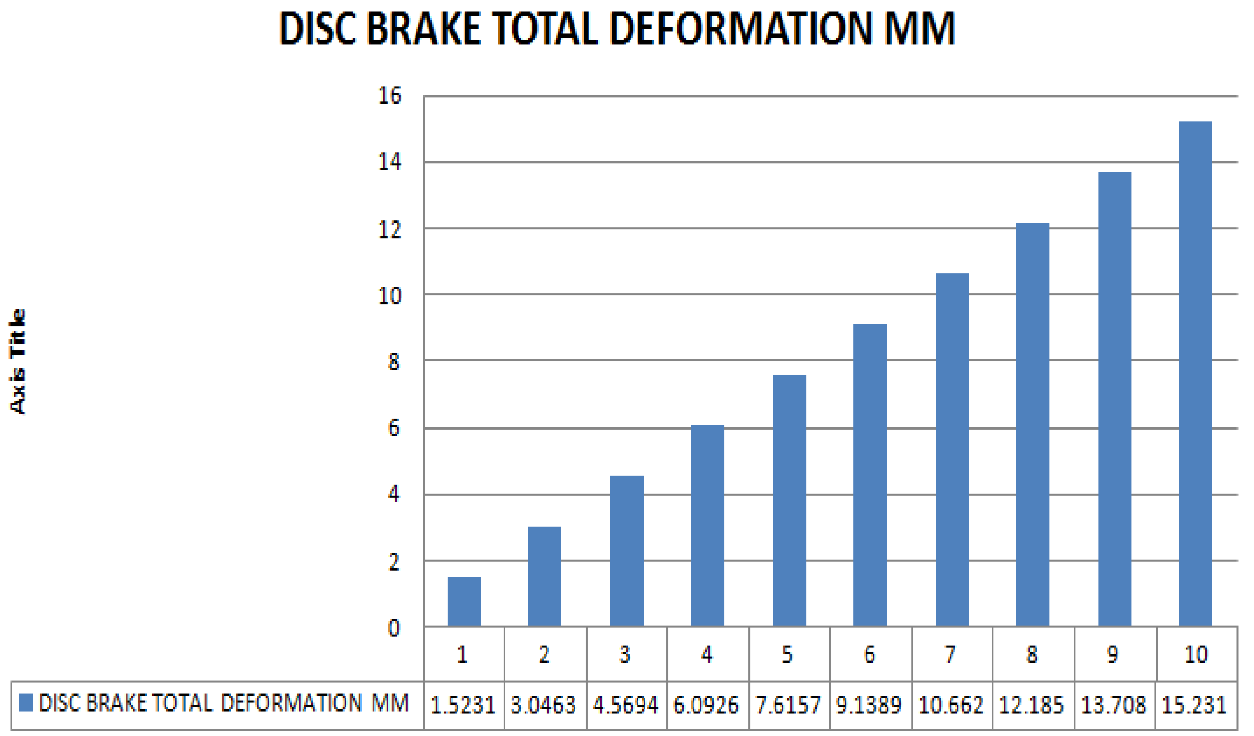

Graph 2: Total Deformation & Frequency by Mode

c) FOR THERMAL ANALYSIS AT FRICTIONAL TEMPERATURE

S.no	Body	Material	Temperature °c	Heat flux W/mm2
1	Disc brake	Aluminum alloy	100.72	0.31535
2	Caliper	Cast iron	100.8	0.020

ACKNOWLEDGEMENT

We would like to express our heartfelt gratitude to Mrs. K. Anoosha, Assistant Professor & Head of the Department of Mechanical Engineering, for her professional guidance and encouragement throughout the project. Our sincere thanks also go to Dr. B. Vijaya Kumar, Professor & Head of the Department, for his expert supervision and valuable suggestions. We appreciate the support of Principal Dr. Koduganti Venkata Rao and the management for providing the necessary facilities, as well as the staff and lab technicians for their assistance. Our thanks extend to our friends, well-wishers, and families for their unwavering support and encouragement.

CONCLUSION

The material selection methods for the design and application of automotive brake disc are developed.
In this project we used the disc and caliper (rotor disc brake).in thesis the material are choose for disc is aluminum alloy
In this project we redesign the disc and caliper in solid work individually in part module. Later the parts are assembled together in assembled module in solid works. Later the assembled component is imported in Ansys software to find out deformation and etc. In ansys software we used three system analysis to find deformations. Stress and temperatures variations.

- In modal analysis we found the total deformation of the component by varying frequency.
- In static structural analysis the study of total deformation stress and frictional stress are determine by rotating disc at momentum (rotational joint load).

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- In thermal analysis the temperature distribution is determined.

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