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MODELLING AND ANALYSIS OF DISC BRAKE ROTOR BY USING VARIOUS MATERIALS

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ABSTRACT

Braking system represents one of the most fundamental safety critical components in modern vehicles like two wheelers and four wheelers. Brake absorbs kinetic energy of the rotating parts (Wheels) and the energy is dissipated in the form of heat energy to the surrounding atmosphere. It decelerates or stops the vehicle. When sudden brake is applied to the disc brake it is subjected to high stress, thus it may suffer structural and wear issues with existing Cast iron and Cast steel. Hence for the better performance and to withstand heavy stresses, by replacing the Aluminium and Carbon fiber reinforced plastic with existing materials Cast iron and Cast steel. The main objective of this project is to model the disc brake using CATIA software and analyze performance under varying braking conditions. The analysis includes evaluating temperature distribution, deformation, and stress distribution through static structural and transient thermal analysis Disk Brake, Structural analysis, Thermal analysis, Ansys

INTRODUCTION THEORY OF BRAKE

In today’s growing automotive market, the competition for better performance vehicle is growing enormously. The racing fans involved will surely know the importance of a good brake system not only for safety but also for staying competitive. The disc brake is a device for slowing or stopping the rotation of a wheel. A brake disc usually made of cast iron or ceramic composites includes carbon, Kevlar and silica, is connected to the wheel and the axle, to stop the wheel. A friction material in the form of brake pads is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. This friction causes the disc and attached wheel to slow or stop. Generally, the
methodologies like regenerative braking and friction braking system are used in a vehicle. A friction brake generates frictional forces as two or more surfaces rub against each other, to reduce movement. Based on the design configurations, vehicle friction brakes can be grouped into drum and disc brakes. If brake disc are in solid body the heat transfer rate is low. Time taken for cooling the disc is low. If brake disc are in solid body, the area of contact between disc and pads are more.

MODELLING OF DISC BRAKE

Creating a disc brake rotor model in CATIA involves several steps, including sketching, extruding, and adding details like holes and fillets. Here's a simplified outline:
1. Sketch: Begin by sketching the profile of the disc brake rotor on the desired plane.
2. Extrude: Extrude the sketch to create the basic shape of the rotor.
3. Holes: Sketch and create any required holes for ventilation or mounting.
4. Fillets: Add fillets to smooth out edges and corners for a more realistic look. 18
5. Details: Add any additional details like branding or markings if needed.

Make sure to refer to CATIA's documentation or online tutorials for detailed steps specific to your version of CATIA

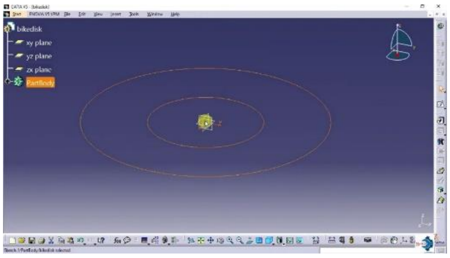


Fig No 3.1 Draw Two Circles Using the Circle Tool

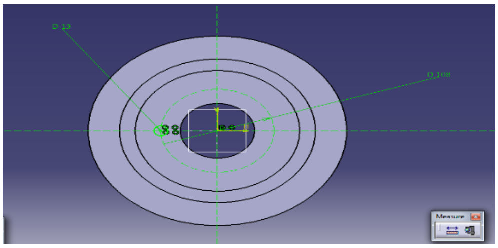
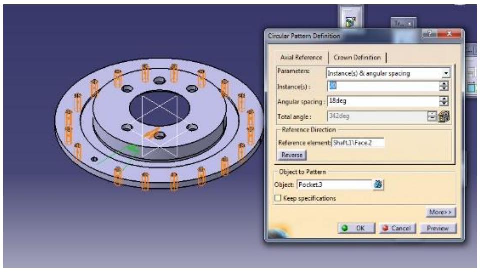


Fig 3.2 Material Removal by Using Extrude tool.



Circular Pattern Definition
Axial Reference | Crown Definition
Parameters: Instance(s) & angular spacing
Instance(s) : 20
Angular spacing : 18deg
Total angle : 342deg
Reference Direction
Reference element: Shaft.1\Face.2
Reverse
Object to Pattern
Object: Pocket.3
☐ Keep specifications
More>>
OK Cancel Preview

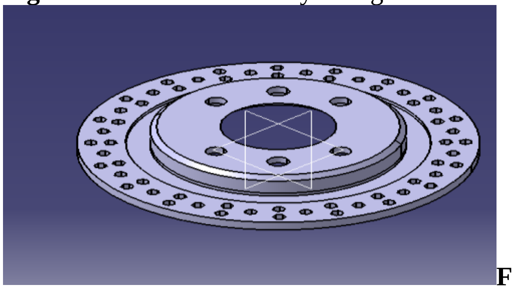


Fig 3.3 Making of Holes Depth of 20mm By Using Extrude Tool

Fig 3.4 Final Model of Disc brake.

ANALYSIS OF DISC BRAKE

Static Structural Analysis of Grey Cast Iron

Process of structural analysis.

a. Select static structure analysis when the ANSYS programme opens.
b. Choose a material that has the right qualities.
c. On the computer, click Geometry and choose a model.
d. Use a triangle mesh to weave the model.
e. Put some load on the model and watch for the outcome.

Static Structural Analysis Of Grey Cast Iron At 1000N

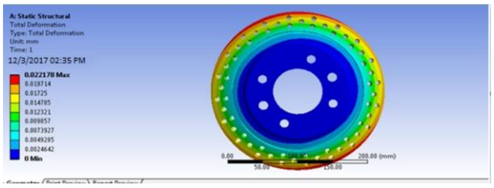


Fig 4.1 Total Deformation of Grey Cast Iron

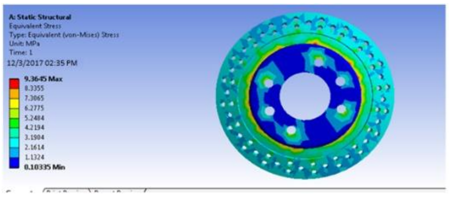


Fig 4.2 Equivalent Elastic Strain Of Grey Cast Iron

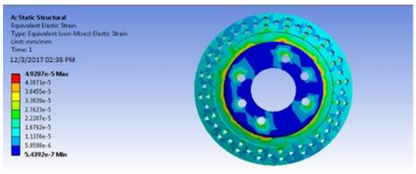


Fig 4.3 Equivalent Stress of Grey Cast Iron

Static Structural Analysis Of Grey Cast Iron At 2000N

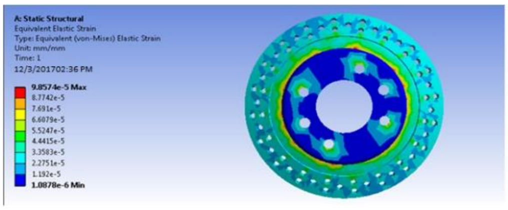


Fig 4.4 Total Deformation of Grey Cast Iron

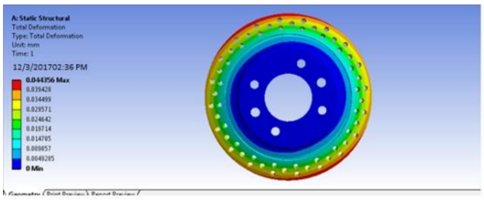


Fig 4.5 Equivalent Elastic Strain Of Grey Cast Iron

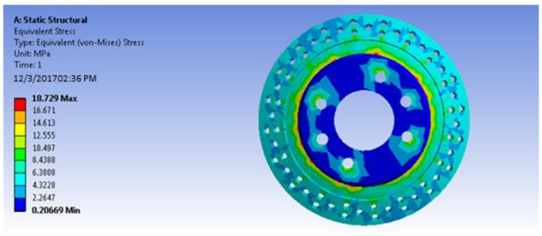


Fig 4.6 Equivalent Stress of Grey Cast Iron

Static Structural Analysis of Aluminium Alloy at 1000 N

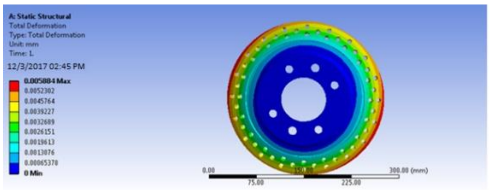


Fig 4.7 Total Deformation of Aliminium Alloy

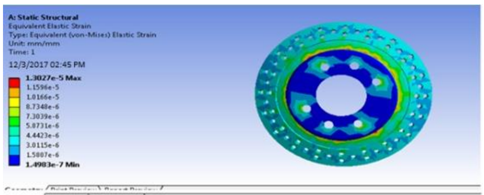


Fig 4.8 Equivalent Elastic Strain of Aliminium Alloy

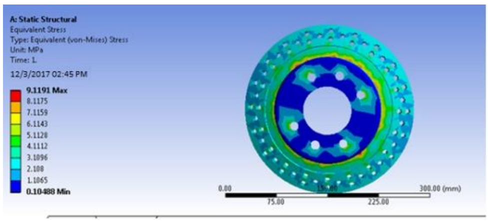


Fig 4.9 Equivalent Stress of Aliminium Alloy

Static Structural Analysis of Aluminium Alloy at 2000 N

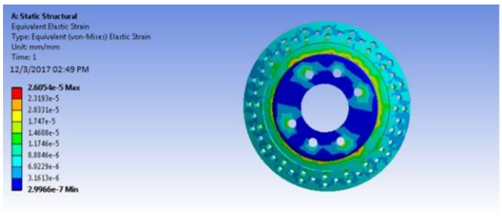


Fig 4.10 Total Deformation of Aliminium Alloy

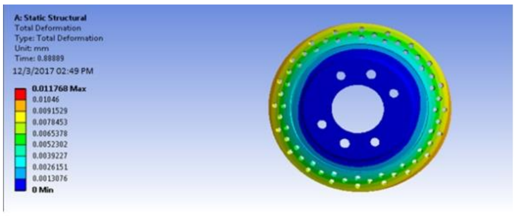


Fig 4.11 Equivalent Elastic Strain of Aliminium Alloy

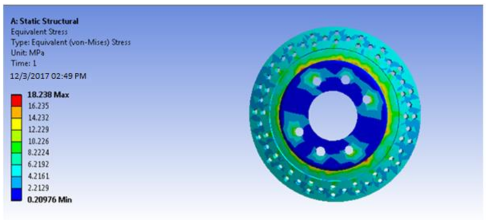


Fig 4.12 Equivalent Stress of Aliminium Alloy

Static Structural Analysis of Aluminium Alloy at 3000 N

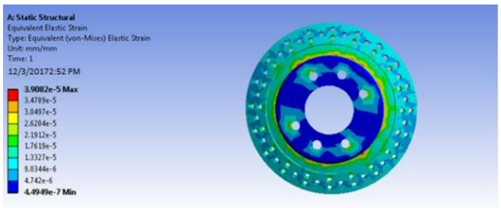


Fig 4.13 Total Deformation of Aliminium Alloy

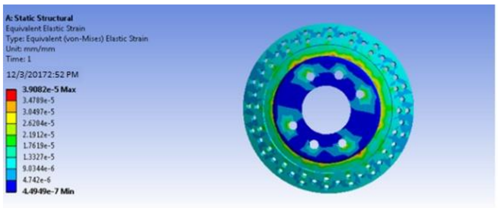


Fig 4.14 Equivalent Elastic Strain of Aliminium Alloy

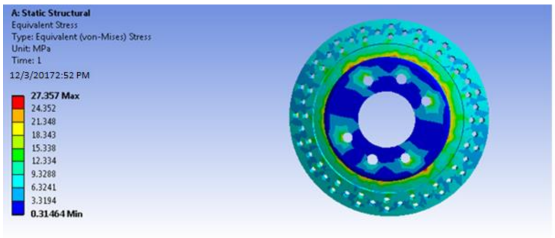


Fig 4.15 Equivalent Stress of Aliminium Alloy

Static Structural Analysis of Nickel Chrome Steel at 1000N

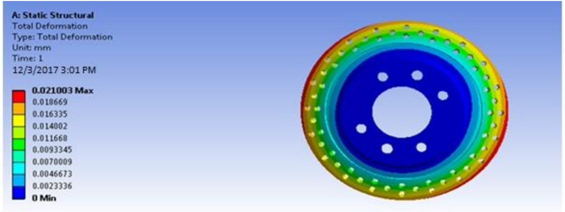


Fig 4.17 Total Deformation of Nickel Chrome

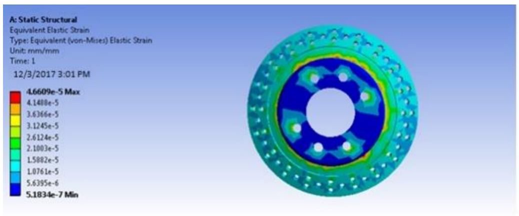


Fig 4.18 Equivalent Elastic Strain of Nickel Chrome Steel

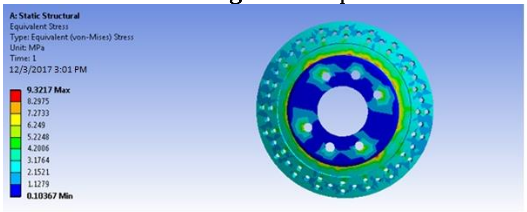


Fig 4.19 Equivalent Stress of Nickel Chrome Steel

Static Structural Analysis of Nickel Chrome Steel at 2000N

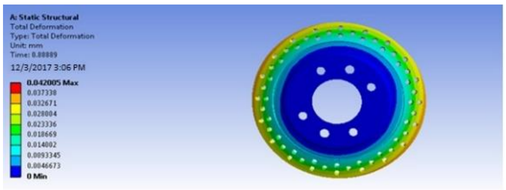


Fig 4.20 Total Deformation of Nickel Chrome

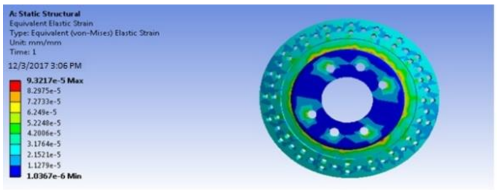


Fig 4.21 Equivalent Elastic Strain of Nickel Chrome Steel

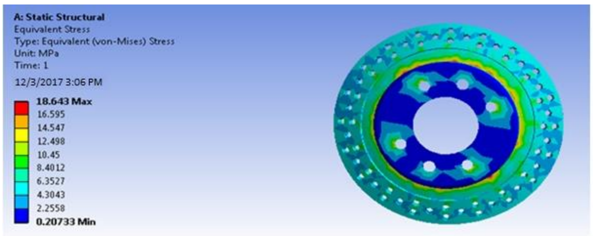


Fig 4.22 Equivalent Stress of Nickel Chrome Steel

Static Structural Analysis of Nickel Chrome Steel at 3000N

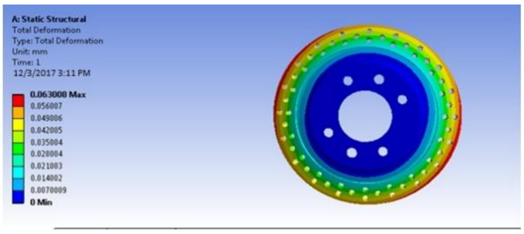


Fig 4.23 Total Deformation of Nickel Chrome

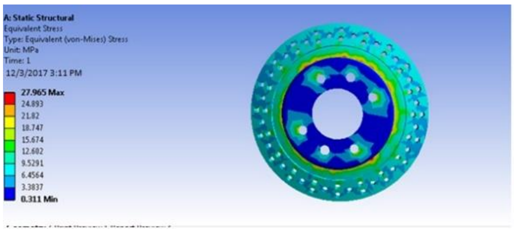


Fig 4.24 Equivalent Elastic Strain of Nickel Chrome Steel

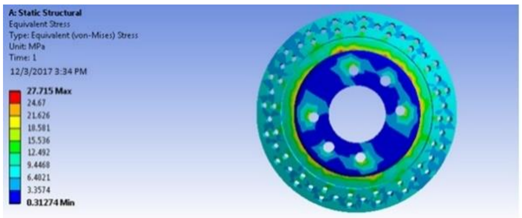


Fig 4.25 Equivalent Stress of Nickel Chrome Steel

6.12 Transient Thermal Analysis of Grey Cast Iron.

a. Select thermal analysis when the ANSYS programme opens.
b. Choose a material that has the right qualities.
c. On the computer, click Geometry and choose a model.
d. Use a triangle mesh to weave the model.
e. Apply temperature on the model and watch for the outcome

Transient Thermal Analysis of Disc Brake Rotor (Grey Cast Iron) at 500 ^{0}c

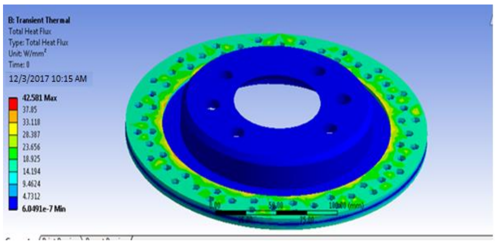


Fig 4.26 Total Heat Flux of Grey Cast Iron

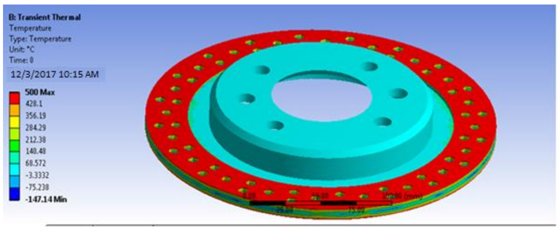


Fig 4.27 Temperature of Grey Cast Iron

Transient Thermal Analysis of Disc Brake Rotor (Grey Cast Iron) at 1000^{0}c

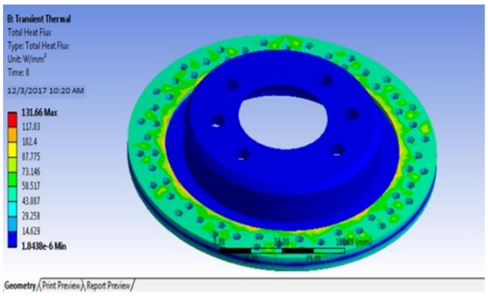


Fig 4.28 Total Heat Flux of Grey Cast Iron

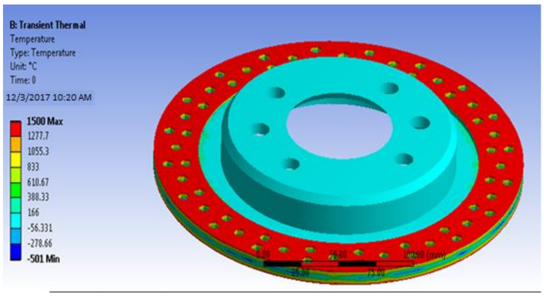


Fig 4.29 Temperature of Grey Cast Iron

Transient Thermal Analysis of Disc Brake Rotor (Grey Cast Iron) at 1500^{0}c

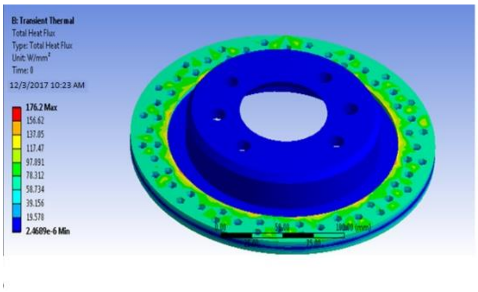


Fig 4.30 Total Heat Flux of Grey Cast Iron

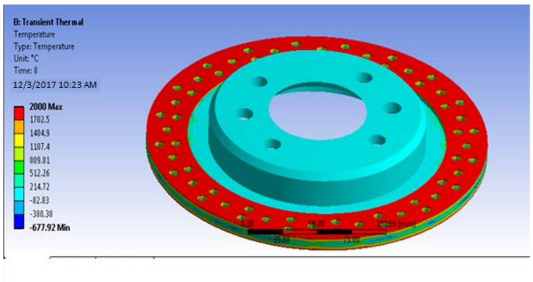


Fig 4.31 Temperature of Grey Cast Iron

Transient Thermal Analysis Aluminium Alloy at 500^{0}c

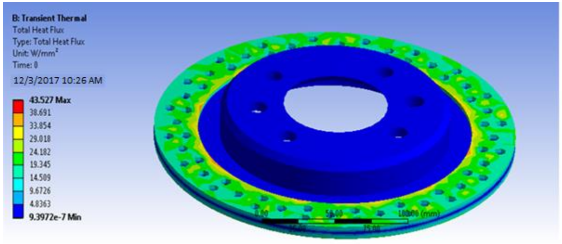


Fig 4.32 Total Heat Flux Of Aliminium Alloy

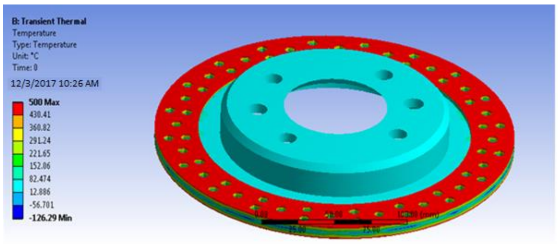


Fig 4.33 Temperature of Aliminium Alloy

Transient Thermal Analysis Aluminium Alloy at 1000^{0}c

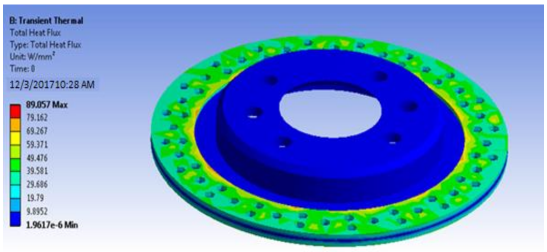


Fig 4.34 Total Heat Flux Of Aliminium Alloy

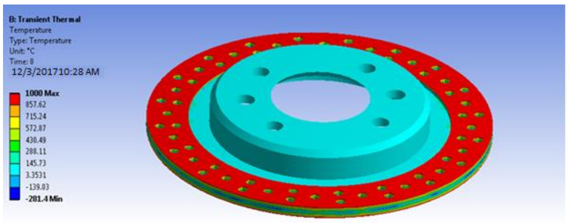


Fig 4.35 Temperature of Aliminium Alloy

Transient Thermal Analysis Aluminium Alloy at 1500^0c

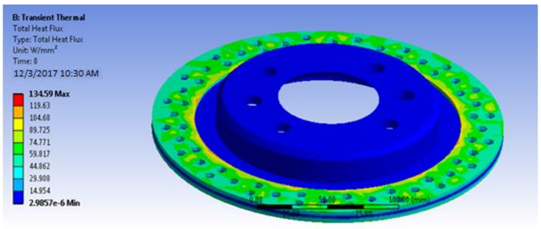


Fig 4.36 Total Heat Flux Of Aliminium Alloy

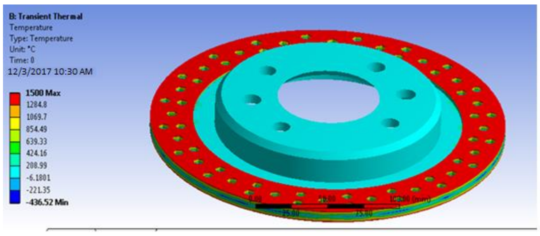


Fig 4.37 Temperature of Aliminium Alloy

Transient Thermal Analysis of Nickel Chrome Steel at 500^0c

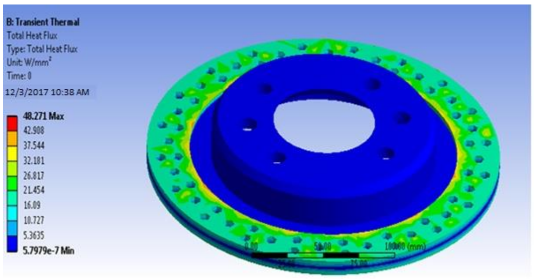


Fig 4.38 Total Heat Flux of Nickel Chrome Steel

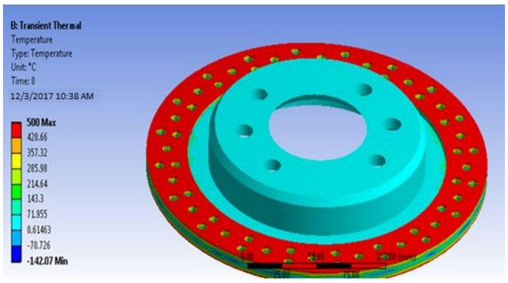


Fig 4.39 Temperature of Nickel Chrome Steel

Transient Thermal Analysis of Nickel Chrome Steel at 1000^0c

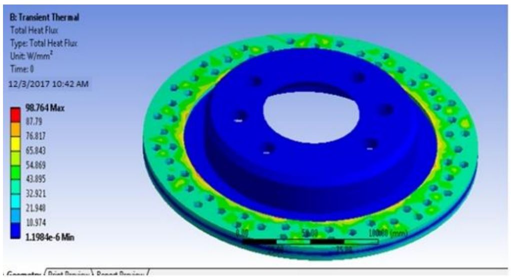


Fig 4.40 Total Heat Flux of Nickel Chrome Steel

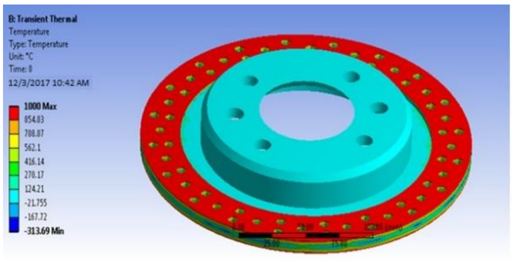


Fig 4.41 Temperature of Nickel Chrome Steel

Transient Thermal Analysis of Nickel Chrome Steel at 1000^0c

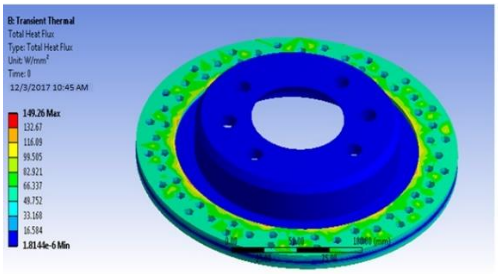


Fig 4.42 Total Heat Flux of Nickel Chrome Steel

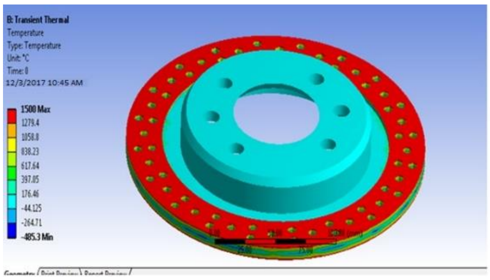


Fig 4.43 Temperature of Nickel Chrome Steel

RESULTS

The actual experiment and analysis yielded the following result, which is verified and interpreted. Catia V5 software was used to model the disc brake rotor. Stress distribution and distorted shape are the outcomes of structural analysis. Additionally, they used transient thermal analysis to examine how temperature affected the disc brake.

Deformation Results

Table 7.2. Deformation table

LOAD(N)	CAST IRON (mm)	ALUMINIUM ALLOY (mm)	NICKEL CHROME STEEL (mm)	CARBON REINFORCED POLYMER (mm)
1000	0.022178	0.00588	0.021003	0.021956
2000	0.044356	0.011768	0.042005	0.043912
3000	0.066534	0.017652	0.063008	0.065868
4000	0.088713	0.023536	0.084011	0.087824

Strain Results

Table 7.2. Strain table

LOAD	CAST IRON	ALUMINIUM ALLOY	NICKEL CHROME STEEL	CARBON REINFORCED
1000	$4.9287e^{-5}$	$1.3027e^{-5}$	$4.6609e^{-5}$	$4.8623e^{-5}$
2000	$9.8574e^{-5}$	$2.6054e^{-5}$	$9.3217e^{-5}$	$9.7246e^{-5}$
3000	0.00014786	$3.9082e^{-5}$	0.00013983	0.00014587
4000	0.00019715	$5.2109e^{-5}$	0.00018643	0.00019449

Stress Results

Table 7.2. Stress table

LOAD(N)	CAST IRON (MPa)	ALUMINIUMALLOY (MPa)	NICKEL CHROME STEEL (MPa)	CARBON REINFORCED POLYMER (MPa)
1000	9.3645	9.1191	9.3217	9.2383
2000	18.729	18.238	18.643	18.477
3000	28.094	27.354	27.965	27.715
4000	37.458	36.476	37.287	36.953

Heat Flux Results

Table 7.2. Heat Flux table

TEMPERATURE (^0C)	CAST IRON (W/mm^2)	ALUMINIUM ALLOY (W/mm^2)	NICKEL CHROME STEEL (W/mm^2)	CARBON REINFORCED POLYMER (W/mm^2)
500	42.581	43.527	48.271	134.41
1000	87.122	89.057	98.764	275.01
1500	131.66	134.59	149.26	415.61
2000	176.2	180.12	199.75	556.21

Comparison of mathematical structural calculation and structural analysis

Table 7.2. Comparision table

LOAD	**CAST IRON**		**ALUMINIUM ALLOY**		**NICKEL CHROME STEEL**		**CARBON REINFORCED**	
S.NO	Mathematical	analytical	Mathematical	Analytical	Mathematical	analytical	Mathematical	Analytical
1000	$5.02041e^{-5}$	$4.9287e^{-5}$	$1.35\ e^{-5}$	1.3027^{e-5}	$4.76\ e^{-5}$	$4.6e^{-5}$	$4.956se\text{-}^{5}$	$4.8623e^{-5}$
3000	$1.50614\ e^{-4}$	0.00014786	$4.0796e^{-5}$	$3.9082e^{-5}$	$1.430\ e^{-4}$	0.00013983	$1.4869\ e^{-4}$	0.00014587
4000	$2.008\ e^{-4}$	0.00019715	$5.4395\ e^{-5}$	$5.2109e^{-5}$	$1.9\ e^{-4}$	0.00018643	$1.982e^{-4}$	0.00019449

LITERATURE SURVEY

1. **Janvijay Pateriya, Raj Kumar Yadav, Vikas Mukhraiya and Pankaj Singh•** Brake Disc Analysis With The Help Of Ansys Software They analysed the effect of thermal and structural loads on a solid disc brake rotor.
2. **Baskara Sethupathi P., Muthuvel A., Prakash N., Stanly Wilson Louis•** They performed Numerical Analysis of a Rotor Disc for Optimization of the Disc Materials. And defined the thermal performance of a disc brake model by using Finite Element Analysis simulations.
3. **K. Sowjanya, Suresh•** Structural Analysis of Disc Brake Rotor Investigated the effect of strength variations on the predicted stress distributions. Aluminium Metal Matrix Composite materials are selected and analysed. The results are compared with existing disc rotor.
4. **Ameer Fareed Basha Shaik, Ch. Lakshmi Srinivas•** Actual disc brake has no holes; design is changed by giving holes in the disc brake for more heat dissipation. Modelling is done in Catia and Analysis is done in ANSYS.
5. **M.A. Maleque, S. Dyuti and M.M. Rahman (Member, IAENG)•** They investigated Suitable material for Disc brake among the cast iron, aluminium alloy, titanium alloy, ceramics and composites. The analysis led to aluminium metal matrix composite as the most appropriate material for brake disc system.

METHODOLOGY

Designing and analyzing a braking system using a combination of cast iron, steel, and carbon fiber involves considering various factors such as material properties, heat dissipation, weight, and cost. Below is a methodology to guide you through the process:

1. Define Design Requirements
2. Conceptual Design
3. Material Selection
4. Modelling
5. FEA Analysis
6. Performance Evaluation

CONCLUSION

In this project analysis of the contact pressure distributions at the disc interfaces using a detailed 3-dimensional model of a real car disc brake. Determination of the braking force is the most crucial aspect to be considered while designing any braking system. The generated braking force should always be greater than the required braking force. The calculation of Stresses comparison Deformations comparison charts and Heat Flux chart helps us to decide the parameters of the disc brake rotor. Modelling and analysis of a disc brake rotor is done to select the best material which is more durable. Space and assembly constraints are also an important factor while designing the rotor body. Find out the value of deformations and stresses due to cause of pressure. We take four different materials Grey Cast Iron, Aluminium Alloy, Nickel chrome steel and Carbon Fiber in our research. Analysis is done on these materials and conclude that Carbon Reinforced polymer shows the minimum stress and deformation values in boundary conditions. So, Carbon Fiber is suggested for future manufacturing

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