# "DESIGN AND ANALYSIS OF BRAKE DISC PLATE USING FINITE ELEMENT ANALYSIS (FEA) "

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**Abstract -** *A brake is a mechanism that applies resistance through friction to a rotating disk in order to decrease or halt the movement of a vehicle. When braking, the contact between the disk and brake pads generates frictional heat, resulting in elevated temperatures. The excessive heat on the surface of the rotor can cause various undesired effects, including thermal elastic instability (TEI), premature wearing, and thermally induced vibrations (TEV). In this project, we examine the thermal and static structural characteristics of the brake disk rotor, comparing the use of Titanium alloy (Ti 550) and the conventional Stainless-Steel material. The analysis is performed in the ANSYS R 19.2 software through finite element modeling of the disc brake rotor in CREO PARAMETRIC 5.0. Ultimately, a comparison is made between the conventional stainless steel and Ti 550 materials, evaluating the magnitude of Von Mises stresses, temperature distribution, and deformation based on the coupled thermal analysis.*

***Key Words***: **FEA, Ansys, Stress, Efficient Brake, Titanium alloy, Creo Parametric**

## 1.INTRODUCTION

Brakes play a vital role in ensuring the safety of vehicles by slowing down or stopping the rotation of wheels. This is achieved by applying brake pads on both surfaces of a rotor or disc, which creates mechanical force to halt the wheel's motion. Brakes are an indispensable component for safe vehicle operation as they convert the car's kinetic energy into heat energy, thereby reducing its speed.

### 1.1 Disc Brake

A disc brake mechanism consists of a robust circular plate affixed to the wheel hub and an immovable housing for the caliper. The housing is linked to a stationary component of the vehicle and encompasses two compartments that contain pistons. Friction-inducing pads, secured by retaining pins and spring plates, are positioned between the pistons and the circular plate. The caliper incorporates passages for fluid flow, enabling the entry and exit of fluid in each compartment while facilitating the process of bleeding. Each cylinder features a sealing ring made of rubber that is situated between the piston and the cylinder.

## 2. LITERATURE REVIEW

**Ali Belhocine and Oday Ibrahim Abdullah et. al. (2021) -** The study used numerical simulations to analyse the behaviour of three brake disc materials. It included 3D thermal analysis to understand heat distribution and a comparative analysis to identify the best material for optimal vehicle braking. Results were visualized using a thermomechanical model to draw conclusions. [1]

**Srushti Newase, Pradnya Kosbe et. al. (2021)-** This research aims to analyze the thermal properties of vented disc brake rotors for Mahindra Bolero. The goal is to find materials for the brake rotors and pads that can effectively dissipate heat generated during braking, while ensuring structural safety.[2]

**Adarsh Bhat et. al. (2021)-** This project analyses the advantages of disc brakes over drum brakes in terms of stopping distance, heat dissipation, and more. While drum brakes have cost benefits, research aims to improve disc brake designs and materials to reduce deformation and improve thermal characteristics.[3]

**Aakash Jawla, Rahul Anand, Shobhit Agarwal et. al. (2020)-** This study uses thermal analysis to investigate the performance of stainless-steel materials in disc brake design, focusing on heat generation during braking and resulting thermal stress. SolidWorks and ANSYS Workbench are used for analysis. The findings will contribute to understanding disc brake thermal behaviour and material selection for improved performance.[4]

**Sanket Darekar, Ajinkya Dhage et. al. (2020)-** The project designs the disc brake of Bajaj Pulsar 220F with 3D models in CATIA software, and analyses the temperature distribution during braking using ANSYS Workbench. The study compares various disc brake models to select an optimized design based on analysis results.[5]

**Bikesh Suwala, Sanjeev Maharjan et.al. (2020)-** The study analyses the importance of disc brake systems in ensuring vehicle safety and designs four-disc rotor models to improve the weight, mechanical, and thermal performance of the original disc brake of Yamaha Fz-25. The analysis suggests that disc rotor model 4 is the best design with improved performance and reduced production cost.[6]

**S.A.M Da Silva, DVV Kallon et. al. (2019)-** This research aims to compare the performance of a grooved-disc brake and a drilled and grooved disc brake rotor under different applied linear loads. The study will analyze parameters like stress concentrations, load, and displacement to identify critical zones on each rotor using Brembo brake rotor design for a Renault vehicle and software analysis.[7]

**Anurag Parag Borse et. al. (2019)-** The abstract discusses the importance of brakes in vehicles and focuses on the analysis of the disc or rotor of a disc brake, which is a commonly used form of brake for motor vehicles. The study analyses the thermo-mechanical behaviour of the brake disc during the braking phase using ANSYS software.[8]

**Joyson Sam Devapaul P, Paul Gnanam J et. al. (2018)-** The project aims to analyse the thermal and structural behaviour of a two-wheeler brake disc using Solid works and Ansys software. The study investigates the effects of different materials on stress, deformation, and temperature distribution in the disc. [9]

**B.Subbarayudu, Ginjala Kishore et. al. (2018)-** The objective of this study is to analyse a ventilated disc brake by creating Finite Element models using SolidWorks and ANSYS. The study aims to determine the optimal design of the brake disc rotor by evaluating its strength under varying heat flow rates and materials with different cross-sectional variations.[10]

**Deekshith Ch et. al. (2017)-** The work is about analysing the thermal and structural behaviour of a disc brake rotor of a vehicle. Two different materials and thicknesses are considered for the analysis using CATIA and ANSYS software. The objective is to compare the temperature distribution and heat flux of the two materials to optimize the rotor's manufacturing using CNC machine.[11]

**Alampally Sainath1, Prathamesh Mahesh Dehadray et. al. (2015)-** This study aims to use ANSYS to analyze how motorcycle disc brakes affect their surface through thermal stress and deformation. The goal is to prevent damage caused by heat generation and identify the best material for improved performance in terms of temperature, stress, and deformation.[12]

**Ali Belhocine, et. al. (2014)-** The study examines the effect of heat and mechanical stress on brake discs using ANSYS11 software. Through modeling, it identifies an ideal geometric design for ventilation in vehicles. The analysis also measures deformation, stress, and pressure distribution. The study's results are consistent with existing literature.[13]

## 3. METHODOLOGY

### 3.1 Design of Existing Rotor Disc1 and New Rotor Disc2

Existing model of disc rotor and new rotor is designed using Creo parametric 5.0 based and analysed using Ansys R 19.2. Following Table No.1 shows the dimensions of brake rotor Disc1 and Disc 2

**Table No.1**: - Dimension of Disc1 and Disc2

| Parameters | Values Disc1 | Values Disc2 |
|---|---|---|
| Rotor outer diameter | 240 mm | 170 mm |
| Rotor inner diameter | 110 mm | 60 mm |
| Rotor thickness | 4 mm | 5.5 mm |
| Rotor disc material | SS 410 | Ti 550 (Ti-6Al-4V) |
| Coefficient of friction (Dry) | 0.3-0.5 | 0.4 |
| Maximum pressure applied | 1 MPa | 1 MPa |

- **Properties of TITANIUM 550 (Ti-6Al-4V) and SS 410**

The following Table No.2 shows the mechanical properties of the Titanium 550 (Ti-6Al-4V) material and Stainless Steel (SS 410)

**Table No.2: -** Mechanical properties of the Ti 550 (Ti-6Al-4V) and SS 410

| Properties | Values Ti 550 (Ti-6Al-4V) | Values SS 410 |
|---|---|---|
| Density (g/cm3) | 4.43 | 7.7 |
| Friction coefficient | 0.3 | 0.4 |
| Elastic modulus (MPa) (Tension) | 1030 | 210 |
| Poisson's ratio | 0.34 | 0.3 |
| Thermal conductivity (W/m ◦ C) | 7.5 | 42.0-62.0 |
| Specific heat J/(kg K) | 586 (20–570 ◦C) | 460 (20–570 ◦C) |

### 3.2 Input parameters for calculation

Rotor disc heat flux is calculated assuming, the bike moving with a velocity 27.78 m/s (100kmph) and the following Table No.3 shows the input parameter for heat flux calculation.

**Table No.3: -** Input Parameter for Heat Flux Calculation

| Parameters | Values |
|---|---|
| Mass of vehicle (m) | 210 kg |
| Initial velocity(u) | 27.78 m/s |
| Final velocity(v) | 0 m/s |
| Brake rotor dia. (OD) | 240 mm |
| Coefficient of friction (μ) | 0.4 |
| Acceleration due to gravity(g) | 9.81 m/s2 |
| Assuming weight distribution on front wheel while braking (Γ) | 0.65 |

### Theoretical calculation

- **Deceleration (a)**

For safe braking purpose, taking deceleration (a)= 18 ft/s2 =(ft/s2)/3.281

**a= 5.49 m/s2**

- **Time (t)**

Time taken to bring the bike at rest= u/a = 27.78/5.49

**t=5.06 sec**

- **Average braking power on the front wheel (qa)**

Braking power qo is given by = (u*a*w)/2*g = (27.78*5.49*210*9.81)/2*9.8

**(qo) = 16013.78 W**

- **Average braking power(qa)= 16013.78*.65*0.5**

**(qa)= 10408.96 W**

**Note: -** The dynamic weight transfer during braking on front and rear axle is 65:35 percent of total vehicle weight respectively. Hence, Weight distribution on front wheels=0.65

Since only one side of brake disc is considered=0.50

- **Swept area (A)**

Swept area of rotor = {π*(0.242-0.182)}/4 = **A=0.0198 m2**

- **Heat Flux (Φ)**

Heat flux is given as = qa /(A*t) = 10408.96/(0.0198*5.49)

**Φ =51947.14 W/m2**

## 4. MODELLING AND ANALYSIS

### 4.1 Modelling in Creo Parametric 5.0

Disc structure significantly defines the air flow characteristics, Existing disc with drilled holes shown in Fig.1 and New disc rotor shown in Fig.2 with different shape and grooves is modelled in Creo 5.0 software.

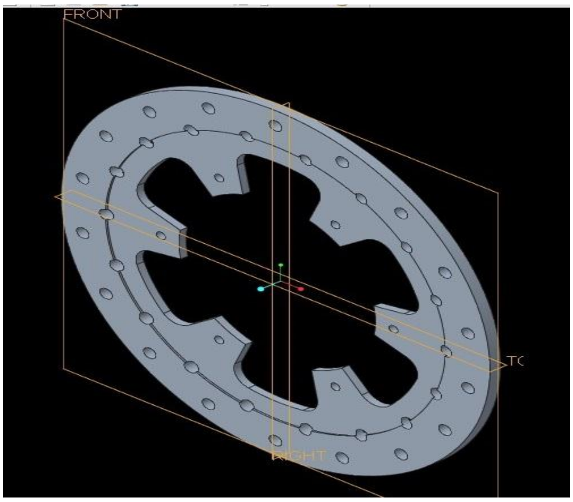


**Fig.1: -** Existing Disc with holes

**Fig.2: -** New Disc with grooves

### 4.2 Analysis

- **Meshing of the disc**

Meshing is important to simulate the boundary technique of problem. Mesh quality has great influence on the results. Mesh size decides the numerical convergence of solution. If the mesh size is poor then it will not give proper results. Fine mesh gives numerical convergence with accurate results.

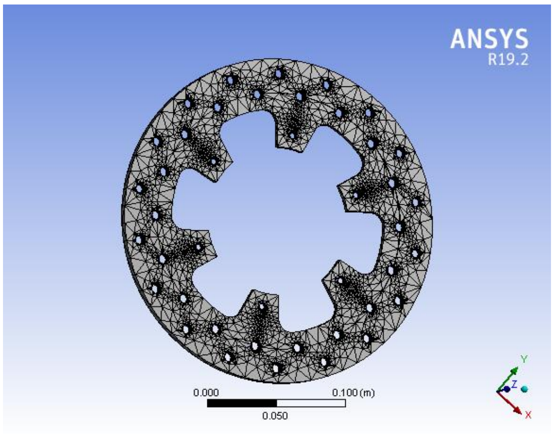


**Fig.3: -** Mesh of Existing Disc

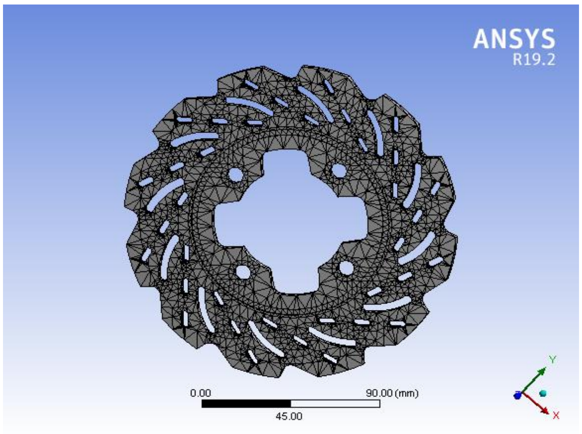


**Fig.4: -** Meshing of New Disc

### 4.3 Steady state thermal analysis

Once the heat flux thermal boundary conditions are created, they are implemented onto the finite element (FE) model to acquire an approximation of the temperature and heat flux distribution within the disc rotor. The thermal boundary conditions for the rotor can be found in Table No.4 provided below, demonstrating the prescribed conditions for the rotor's thermal behavior.

**Table No.4: -** Thermal Boundary condition values

| Parameters | Values |
|---|---|
| Heat flux (W/m$^2$) | 51947.14 (W/m$^2$) |
| Convective heat transfer coefficient (W/m$^{2}$) | 100 (W/m$^2$) |
| Ambient temperature ($^o$C) | 22 $^o$C) |

### 4.4 Static structural analysis

Static analysis determines stress, strain, deformation in structure or component caused by loads that do not induce inertia and damping effects. This project deals with the study of stress, deformation on different brake disc models under static condition. Pressure is applied on the swept area of brake disc and the bolt holes are fixed. Static structure analysis is performed with combined thermal loads on the rotor. The following Table No.5 shows the boundary conditions parameters for static structural analysis.

**Table No.5: -**Static Structural Boundary condition values

| Parameters | Values |
|---|---|
| Support | Fixed |
| Angular Velocity (rad/s) | 116.64 rad/s |
| Pressure on Disc (MPa) | 1 MPa |

## 5. RESULTS

### 5.1 Thermal Analysis results

- **Maximum values of temperature in Disc1 and Disc2**

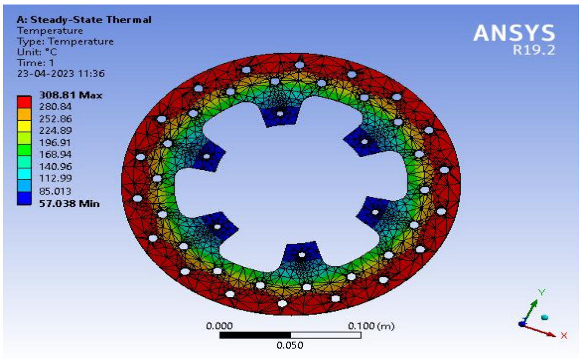


**Fig.5:-** Max temp in SS410 Disc 1 is 308.81oC

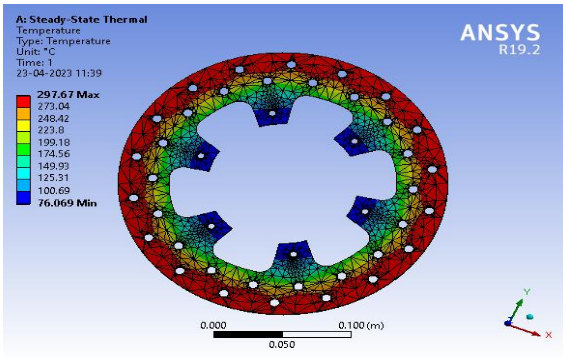


**Fig.6:-**Max temp in Ti550 Disc 1 is 297.67oC

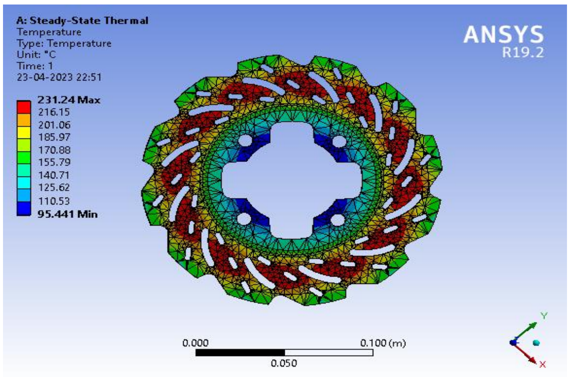


**Fig.7**:- Max temp in SS410 Disc 2 is 231.24°C

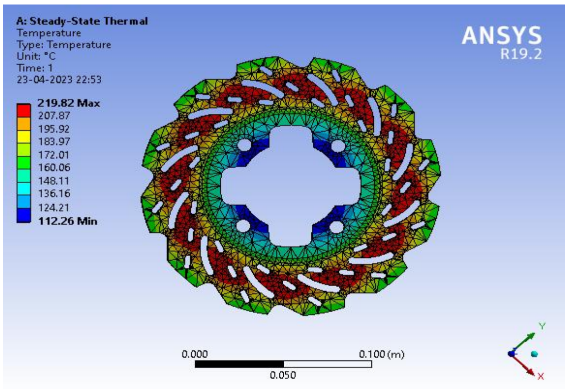


**Fig.8**: Max temp in Ti550 Disc 2 is 219.82°C

### 5.2 Static structural analysis results with combined thermal loads

- **Maximum values of Von Mises stress in Disc 1 and Disc 2**

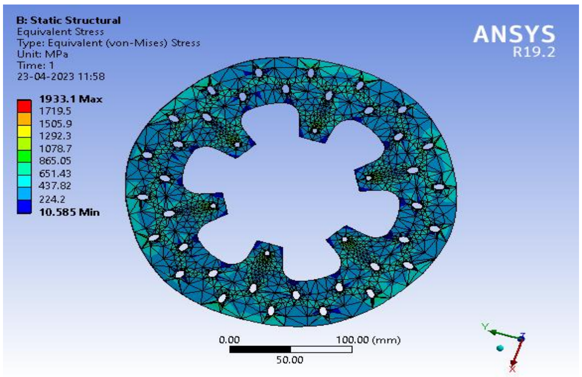


**Fig.9**: Max Stress in SS410 Disc 1 is 1933.1MPa

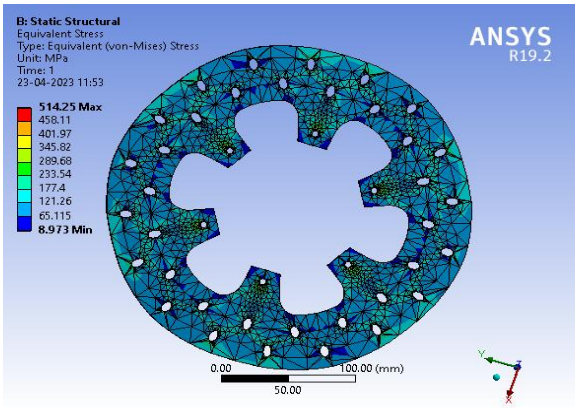


**Fig.10**: -Max Stress in Ti550 Disc 1 is 514.2MPa

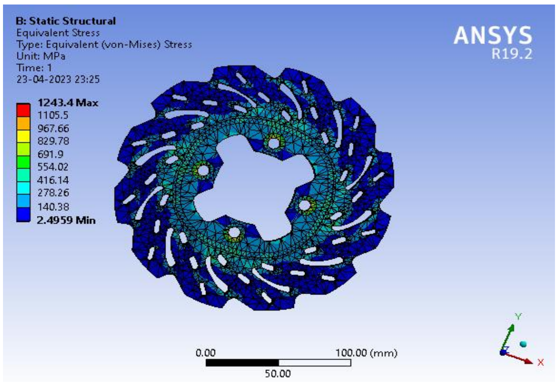


**Fig.11**: Max Stress in SS410 Disc 2 is 1243.4MPa

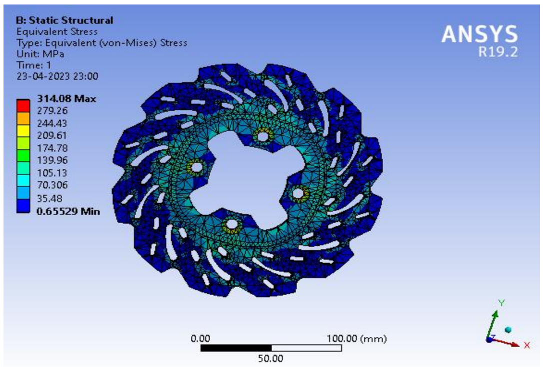


**Fig.12**: Max Stress in Ti550 Disc2 is 314.08 MPa

- **Maximum values of Total Deformation in Disc 1 and Disc 2**

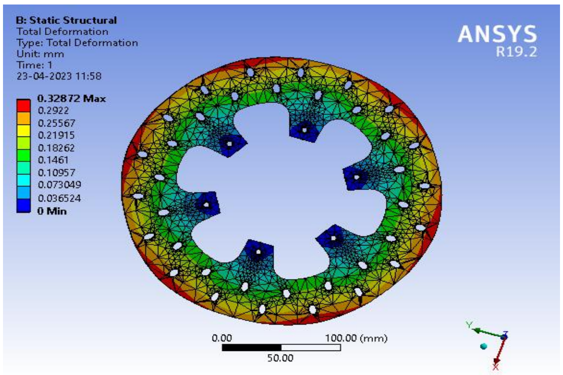


**Fig.13**: Total deformation in SS410 Disc1 is 0.328mm

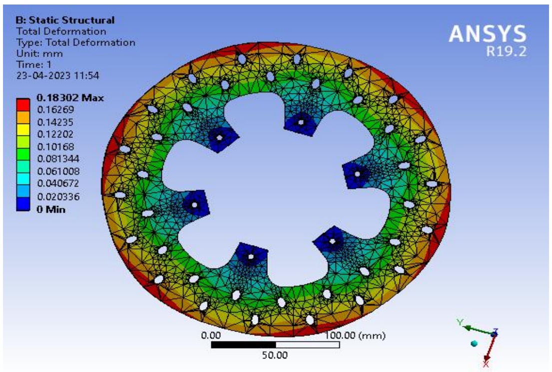


**Fig.14**: Total deformation in Ti550 Disc 1 is0.183mm

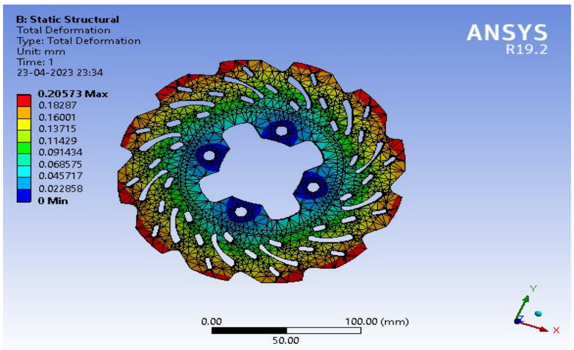


**Fig.15**: Total deformation in SS410 Disc 2 is 0.205mm

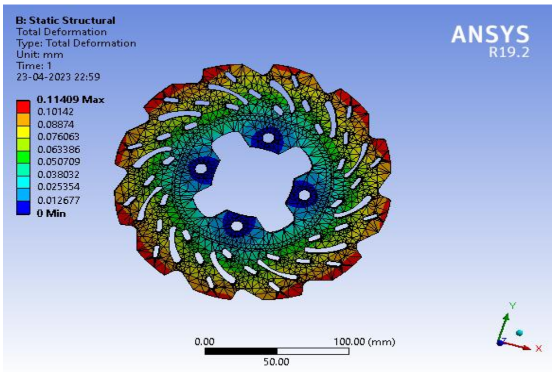


**Fig.16**: Total deformation in Ti550 Disc 2 is 0.114mm

### 5.3 Result Comparison

The steady state thermal and coupled static structural analysis gives the values of Temperature, Stress and Deformation in Disc 1 and Disc 2. The comparison is done in the following tables to understand thermal and structural load variation due to change in design and material.

**Table No.6: -** Max Temp. values in Disc 1 & Disc 2

| Material | Max Temp. (°C) in Disc1 | Max Temp (°C) in Disc2 |
|---|---|---|
| SS 410 | 308.81°C | 231.24 °C |
| Ti 550 | 297.67 °C | 219.82 °C |

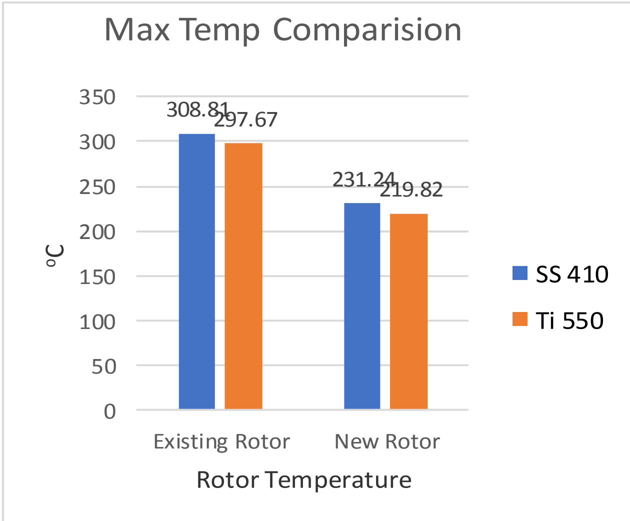


**Chart-1**: Max Temp. Comparison Chart.

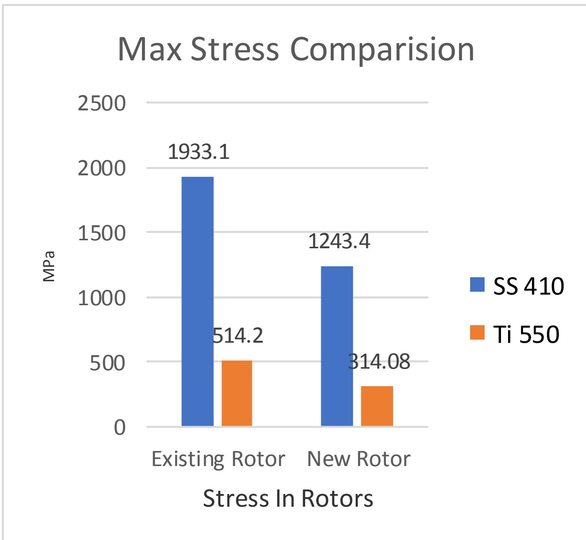


**Chart-2**: Max Stress Comparison Chart.

**Table No.7: -** Max Stress values in Disc 1 & Disc 2

| Material | Max Von Mises Stress (MPa) in Disc1 | Max Von Mises Stress (MPa) in Disc2 |
|---|---|---|
| SS 410 | 1933.1 MPa | 1243.4 MPa |
| Ti 550 | 514.2 MPa | 314.08 MPa |

**Table No.8: -** Max Deformation values in Disc1 & Disc 2

| Material | Total Deformation (mm) in Disc1 | Total Deformation (mm) in Disc2 |
|---|---|---|
| SS 410 | 0.328 mm | 0.205 mm |
| Ti 550 | 0.183 mm | 0.114 mm |

## 6. CONCLUSION

### From the above comparison, the following points can be concluded

- Material SS 410 exhibits higher maximum temperatures in both Disc1 and Disc2 compared to Ti 550, indicating that it may experience higher thermal loads during braking.
- Material SS 410 also shows higher maximum Von Mises stress values in both Disc1 and Disc2, suggesting that it may experience higher mechanical loads during braking.
- Material SS 410 has higher total deformations in both Disc1 and Disc2 compared to Ti 550, indicating that it may undergo more deformation or wear during braking.
- Material Ti 550 exhibits lower values for maximum temperature, maximum Von Mises stress, and total deformation in both Disc1 and Disc2, suggesting that it may have better thermal and mechanical performance compared to SS 410.

Based on the given data, Ti 550 may be a more suitable material for brake disc rotors as it shows lower values for temperature, stress, and deformation, which could potentially lead to better performance and longer durability under braking conditions.

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