



Topology Optimization of Brake Disc Rotor

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ABSTRACT

A braking system is a safety gadget that gives safety to the passengers to lower the probability of a twist of fate. The braking control or deceleration of an automobile is carried both by the use of a drum brake machine or a brake disc device drum brake system is the conventional machine which an extended braking system results in the less braking efficiency whereas, the disc brake gadget is powerful in comparison to drum brake because it's having a shorter braking system. The main objective is to increase a brake disc rotor with specific profiles additionally it contains vent holes to grow its efficiency. At the same time, the Modelling of the brake disc rotor goes to be using SOLIDWORKS with the aid of taking the BAJAJ PULSAR 150 brake disc rotor dimensions as a reference. The heat dissipation from the brake disc rotor and additionally its capability of resisting structural loads state the efficiency of the design. The Numerical simulation like static structural and thermal analysis will be executed in ANSYS. Total deformation, equivalent strain, equivalent elastic stress, and aspect of protections are to be executed in structural analysis whereas thermal analysis, general warmness flux, and temperature may be executed. Topological optimization might be finished to the brake disc rotor if you want to reduce its weight which is indirectly answerable the increasing its effectiveness.

KEYWORDS: Disc Brake, Staructural Analysis, Thermal Analysis, Numerical Simulation

1. INTRODUCTION

Generally, one of Necessity system required to control the automobile is braking system. They are mainly two systems are employed in automobiles those are drum braking system and disc braking systems. As compared with the disc braking system drum braking system is less efficient because in drum braking system more heat is generated while applying the brakes to the vehicle as compared to the disc braking system. In general, whenever brakes are applied high heat energy produced between brake pads and brake drums in brake drum system. And due to the brake drum system is closed system it is difficult to provide air supply in order to reduce the heat.so in order to overcame this difficulty drum braking system disc braking system is widely used in automobiles because of its effective performance while

applying the brakes it provides instant braking to the vehicle with a light weight arrangement which increases the efficiency of the engine and disc is directly contact to the surrounding air so that it is very is to circulate the air and more heat transfer can be archived by using disc brake system in disc braking system heat is transferred through free convection. In this project we are providing slots on in order reduce weight of the disc and also helps to circulate more air through the disc of a disc braking system. Generally cast-iron is manufactured the disc because of its excellent thermal conductivity high heat resistant capacity and long life. In this project we are going heat treated aluminum alloys, carbon fibre reinforced carbon composite(CFRC),steel alloys. In order ease the manufacturing of disc with different slots and to get more heat transfer through the disc heated

aluminium is used. Carbon fibre reinforced carbon composite is used to increase. The High melting point, low coefficient of thermal expansion and high toughness. Aluminium alloys are used to provide the high strength and reducing weight of the disc brake than the cast iron. The aim of this project is to develop a brake disc rotor with different profiles also it's vent holes to increase its efficiency. While the Modelling of brake disc rotor is going to be done using SOLIDWORKS by taking the BAJAJ PULSAR 150 brake disc rotor dimensions as a reference. The heat dissipation from the brake disc rotor and also its capability of resisting structural loads states the efficiency of the design. The Numerical simulation like static structural and steady state thermal analysis will be done in ANSYS. Total deformation, Equivalent stress (von-mises), Equivalent elastic strain and factor of safety is going to be done in structural analysis whereas in steady state thermal analysis, total heat flux and temperature will be done. Topological optimization will be done to the brake disc rotor in order to reduce its weight which indirectly responsible for the increasing its effectiveness

2. RELATED WORK

OBJECTIVE:

To analyze the brake disc with different profiles and with different vent holes to decrease the weight of the brake disc with topological optimization. To maximize the heat dissipation rate which helps to give an efficient cooling to increase its lifespan.

PROBLEM DISCUSSION:

The issue with disc brake results due to uneven stresses and heat dissipation at the time of applying brake. the failure if disc brake occurs due to rusting of disc brake material, braking and cracking. The efficient working of brake system depends on how the brake behaves at high temperatures

LITERATURE REVIEW:

[1]. Design and Analysis of Disc Brake Rotor

Author: Venkatramanan R*, Kumaragurubaran SB*, Vishnu Kumar C*, Sivakumar S#, Saravanan B\$.

Year of publishing: 2021

In this research by Venkatramanan R* they mainly focus on thermal analysis of disc brake and calculated temperature distribution and heat flux finally they

concluded that copper line acts as a good heat dissipater. Based upon the work, with copper linear the maximum temperature is very low (i.e., 335.98°C) as compared with lined one (i.e., 603.59°C).

[2]. Aluminum Brake Disc

Author: Marc Rettig¹, Jaroslaw Grochowicz¹, Klaus Kaesgen¹, Thomas Wilwers¹, Ricardo Labrador², Idurre Gaztanaga², Nerea Egidazu², Clemens Verpoort³, Agusti Sin⁴, Francesco Vannucci⁴, Valentina Iodice⁴

In this research by Marc Rettig¹: this paper, the comparison between existing material cast iron disc with aluminum disc in order to improve the efficiency of disc gives better advantages like it reduces the disc weight and stable friction level about wide temperature and no corrosion

[3]. A computational study on structural and thermal behavior of modified disk brake rotors

Author: M.H. Pranta, M.S. Rabbi, S.C. Banik, M.G. Hafez, Yu-Ming Chu

Year of publication: 2021

In this research by M.H. Pranta: steady-state thermal and static structure analysis has been performed for proposed disk brake rotors with the combination of holes, straight slots, vanes, and edge cuts and compared the characteristics with the reference rotor.

[4]. Thermo-mechanical analysis of disk brake using finite element analysis

Author: Vishvajeet, Faraz Ahmad, Muneesh Sethi, R.K. Tripathi

Year of publication : 2021

In this research by Vishvajeet: In this paper we studied about the rise in temperature of an automotive disc brake at the time of braking with the application of braking torque. The rotor was further loaded with thermo-mechanical cyclic stresses to analyse the durability and fatigue factor of safety of disc

[5]. Improvement in performance of vented disc brake by geometrical modification of rotor

Author: S. Mithlesh, Zubair Ahmad Tantray, Mohit Bansal, Kotte V. Kartik Pawan Kumar, Varun Sai Kurakula, Manpreet Singh

Year of publication: 2021

In this research by S. Mithlesh: In this research work the hole diameter of the rotor was increased and subsequently disk plate thickness was also increased to maintain the adequate structural. The analysis was

carried on proposed designs for total deformation, stress and life span. The output does not affect the increase in hole dia.

[6].Thermal analysis on car brake rotor using cast iron material with different geometries

Author:Ashish Kumar Shrivastava, Rohit Pandey, Rajneesh Kumar Gedam, Nikhil Kumar, T. RaviKiran

Year of publication: 2021

In this research by Ashish Kumar Shrivastava: In This paper gives information about the modification of brake disc rotor. while designing the rotor body Space and assembly constraints are also an important factor increased space geometry can cause an early failure led to short life span of brake disc rotor.

[7].Design and analysis of disc brake rotor using different profiles

Author:S. Abrar Ahmed, V. Ayush Kumar, S. Gokul, P.VijayC. Parthasarathy

Year of publication: 2020

In this research by S. Abrar Ahmed: In this paper the inner and outer boundaries are preserved, changes are made only in the intermediate patterns between the boundaries. The static structural and steady state thermal analysis of brake disc rotor is done

[8].Numerical investigation of thermo-mechanical properties for disc brake using light commercial vehicle

Author:HabtamuDubale,VelmuruganParamasivam, Eneyw Gardie,Ewnetu TeferaChekol, Senthil Kumaran Selvaraj

Year of publication: 2021

In this research byHabtamuDubale: The finite element analysis has been performed to assess the various types of disc brake profiles' performance. The primary intent of the study was to perform a thermo-mechanical analysis on selected three-disc brake profiles. Thus, solid-type, drilled-type, and grooved-type disc brake profiles.

3. PROPOSED WORK

DIMENSIONS OF THE DISC BRAKE:

BAJAJ PULSER 150CC

Outer diameter	260 mm
Inner diameter	190 mm
Thick ness	5 mm
No.of vent holes	12
Diameter of vent holes	8 mm

Table:1

MODELLING IN SOLID WORKS: In this project design of Bajaj pulser 150 brake disc dimensions are considered. The standard disc and modified discs are designed on solid works. There are three types of materials are used are heat treated aluminum alloy, carbonfiber reinforced carbon composite and steel alloys.

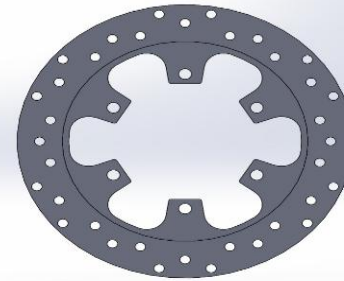


Fig:1 Standard Disc

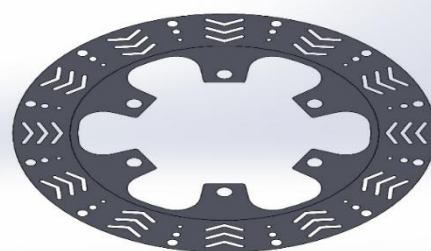


Fig:2 Modified Disc1

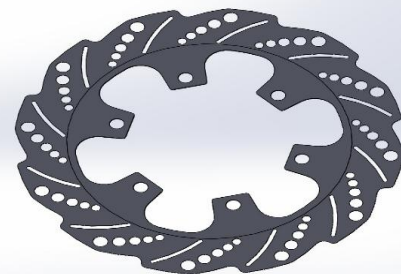


Fig:3 Modified Disc2

MATERIAL INFORMATION: In this project we are using heat treated aluminum alloy and carbon fiber reinforced carbon composite and steel alloys which is suitable for disc brake rotor and Material composition mentioned in the below.

HEAT TREATED ALUMINUM ALLOY:(AL6061 T6)

Material composition:

Table:2

STEEL ALLOY:(40cr4mo3)

Young's Modulus	6890 MPa
Poisson's Ratio	0.33
Bulk Modulus	6754.9 MPa
Shear Modulus	2590.2 MPa
Isotropic Coefficient of Thermal Expansion	2.6e+06 1/°C
Tensile Ultimate Strength	241 MPa
Tensile Yield Strength	145 MPa
Isotropic Thermal Conductivity	0.167 w/mm°C
Density	2.7e-06 kg/mm ³

MATERIAL COMPOSITION:

Young's Modulus	2e+05 MPa
Poisson's Ratio	0.3
Bulk Modulus	1.6667e+05 MPa
Shear Modulus	76923 MPa
Isotropic Coefficient of Thermal Expansion	1.26+07 1/°C
Tensile Ultimate Strength	655 MPa
Tensile Yield Strength	415 MPa
Isotropic Thermal Conductivity	0.422 w/mm°C
Density	8.05e-06 kg/mm ³

Table:3

CARBON FIBRE REINFORCED CARBON COMPOSITE(CFC)**MATERIAL COMPOSITION:**

Young's Modulus	80000 MPa
Poisson's Ratio	0.33
Bulk Modulus	78431 MPa
Shear Modulus	30075 MPa
Tensile ultimate strength	300 MPa
Tensile yield strength	235 MPa
Isotropic Thermal Conductivity	0.0172 w/mm°C
Specific heat constant pressure	7.354e+05 mJ/kg°C
Density	1.59e-06 kg/mm ³

Table:4

ANALYSIS:

The design brake disc rotor in solid works is imported in Ansys geometry in step file format and study state thermal analysis is carried out for the imported geometry with three different assignments of materials by applying the boundary conditions like temp and coefficient of convention film to the imported geometry tetrahedral mesh is done for the design geometry in solution total heat flux and temperature distribution at different nodes are evaluated. Static structural boundary conditions are braking pressure acting on the braking surface area fixed support is applied to the given slots for bolting moment is applied to the imported geometry in solution total deformation equivalent elastic strain equivalent von-mises stress.

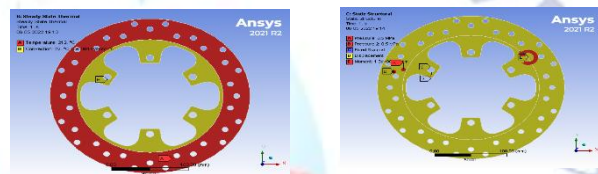
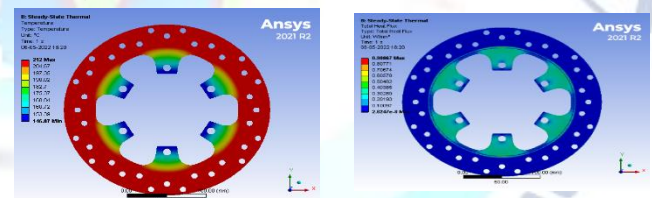
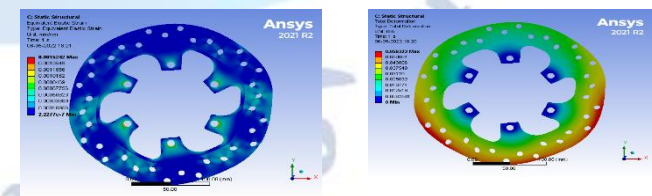
BOUNDARY CONDITIONS FOR ENGINE BRAKE DISC ROTOR:

Figure:5

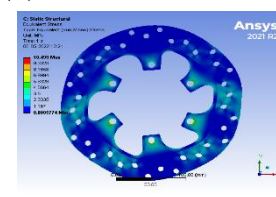
STATIC STRUCTURAL AND STEADY STATE THERMAL ANALYSIS:**Heat Treated Aluminum Alloy(AL6061 T6)****Standard Disc:****Steady state thermal:**

Fig(a)Fig(b)

Figure 6a:(a) temperature(b)heat flux

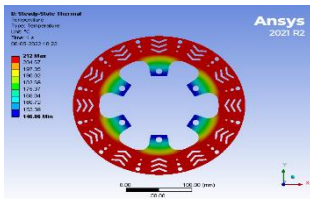
Static structural:

Figure(a)Figure(b)

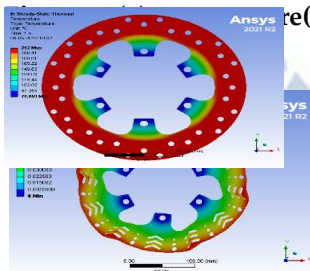


Figure(c)

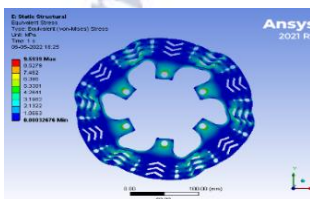
Figure6b:(a)totaldeformation (b)equivalent elastic strain (c) elastic stress
Modified disc:1
Steady state thermal:



Figure(a)Figure(b)

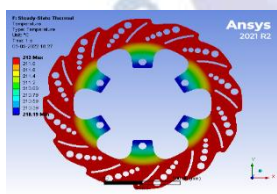


Figure(a)Figure(b)



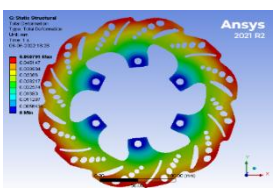
Figure(c)

Figure7(b)(a)total deformation (b) equivalent elastic strain(c) elastic stress
Modified disc 2:
Steady state thermal:

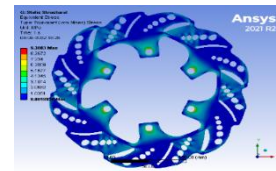
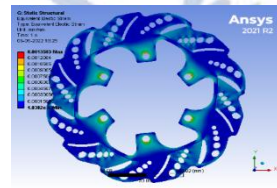
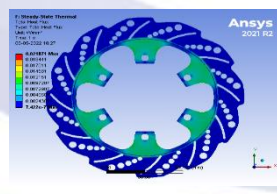


Figure(a)Figure(b)

Figure8a:(a) temperature (b)heat flux
Static structural:

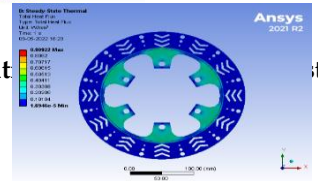


Figure(a)Figure(b)



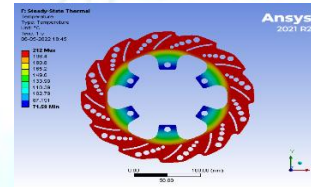
Figure(c)

Figure8(b)(a)total deformation (b) equivalent elastic strain(c) elastic stress
Steel Alloy:(40cr4mo3)
Standard Disc:
Steady state thermal:

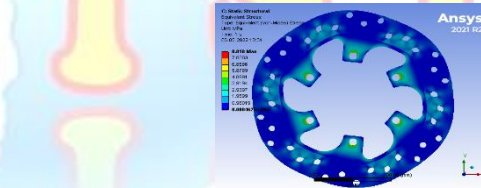
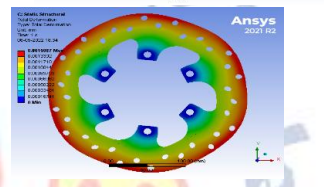


Figure(a)Figure(b)

Figure9a:(a) temperature (b)heat flux

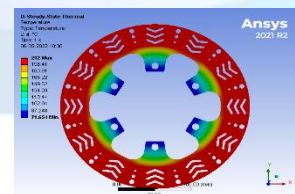


Figure(a)Figure(b)



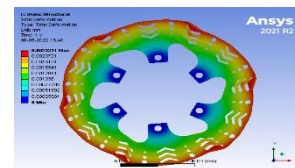
Figure(c)

Figure9(b)(a)total deformation (b) equivalent elastic strain(c) elastic stress
Modified disc 1:
Steady state thermal:

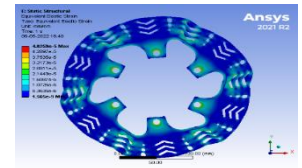


Figure(a)Figure(b)

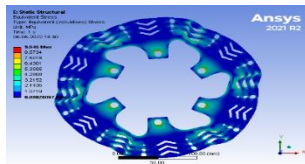
Figure10a:(a) temperature (b)heat flux
Static structural:



Figure(a)



Figure(b)

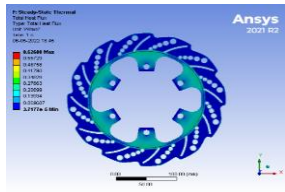


Figure(c)

Figure10(b)(a)total deformation (b) equivalent elastic strain(c) elastic stress

Modified disc 2:

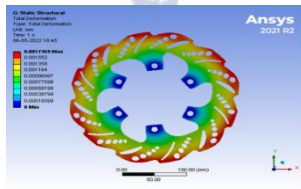
Steady state thermal:



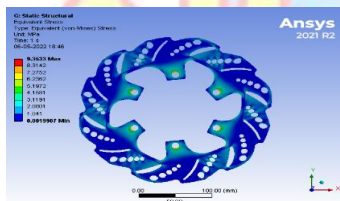
Figure(a)

Figure11a:(a) temperature (b)heat flux

Static structural:



Figure(a)Figure(b)



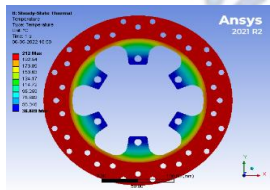
Figure(c)

Figure11(b)(a)total deformation (b) equivalent elastic strain(c) elastic stress

Carbon fiber reinforced carbon composite(CFC)

Standard Disc:

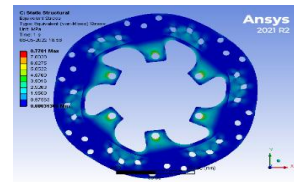
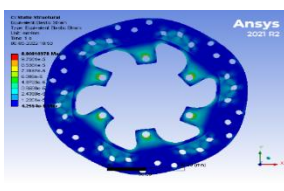
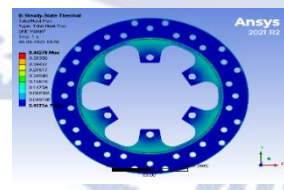
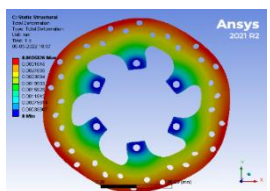
Steady state thermal:



Figure(a)Figure(b)

Figure12a:(a) temperature (b)heat flux

Static structural:

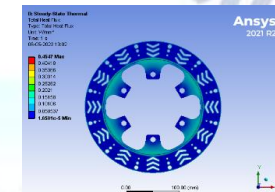


Figure(c)

Figure12(b)(a)total deformation (b) equivalent elastic strain(c) elastic stress

Modified disc:1

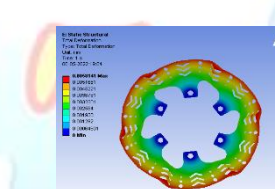
Steady state thermal:



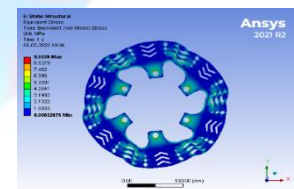
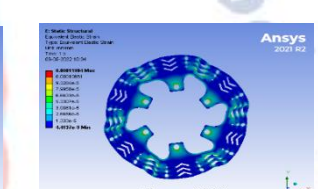
Figure(a)Figure(b)

Figure13a:(a) temperature (b)heat flux

Static structural:



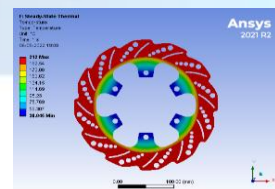
Figure(a)Figure(b)



Figure(c)

Figure13(b)(a)total deformation (b) equivalent elastic strain(c) elastic stress

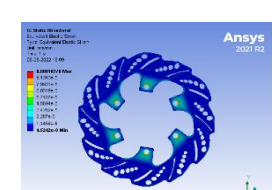
Modified disc 2:



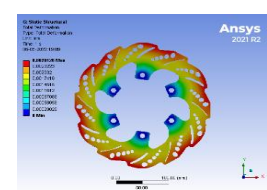
Figure(a)Figure(b)

Figure14a:(a) temperature (b)heat flux

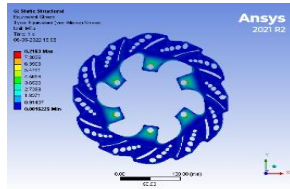
Static structural:



Fig(a)



Fig(b)



Fig(c)

Figure14(b)(a)total deformation (b) equivalent elastic strain(c) elastic stress

Topological optimization:

In topological density optimization the mass reduction takes place only where there is no load applied and the area is free from the boundary conditions so that, for this brake disc the geometry is optimized by removing a small portion of area at the finger like projections which supports the brake disc to the wheel. The optimized shape is redrawn in SOLIDWORKS to get a clear enhancement of optimized area.

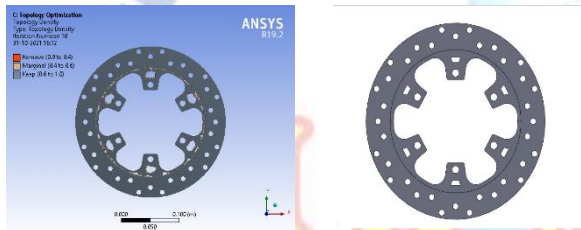


Fig15. Topological optimization for Existing brake disc

4. RESULTS

As per results obtained from Ansys we compared different parameters for various discs which is made up of different materials in Ansys, and in order to find the most efficient disc we tabulated the values obtained from ansys and decided the efficient disc.

Table:5

Material -Carbon fiber reinforced carbon composite (CFC)				
Steady state thermal				
Disc type	Temperature (°C)		Total heat flux (W/mm ²)	
	max	Min	max	Min
Standard disc	212	36.889	0.44276	5.1572×10^{-7}
Modified disc 1	212	36.885	0.4547	1.6581×10^{-5}
Modified disc 2	212	36.845	0.44621	3.6941×10^{-5}

Table:6

Material -Steel Alloy (40cr4mo3)				
Steady state thermal				
Disc type	Temperature (°C)		Total heat flux (W/mm ²)	
	max	Min	max	Min
Standard disc	212	71.659	0.63099	3.3781×10^{-6}
Modified disc -1	212	71.654	0.64056	1.681×10^{-5}
Modified disc -2	212	71.59	0.62688	3.7177×10^{-5}

Table:7

Disc type	Material -Steel Alloy (40cr4mo3)					
	Static structural					
	Total deformation(mm)		Equivalent elastic strain(mm/mm)		Equivalent stress(MPa)	
	max	min	Max	Max	Min	Max
Standard disc	0.0015067	0	4.411×10^{-5}	2.4851×10^{-9}	8.818	0.00046268
Modified disc -1	0.002331	0	4.8259×10^{-5}	1.565×10^{-9}	9.645	0.00028067
Modified disc -2	0.0017459	0	4.6782×10^{-5}	1.9237×10^{-8}	9.3533	0.0019907

Table:8

Material -Heat treated aluminum alloy (Al6061 T6)				
Steady state thermal				
Disc type	Temperature (°C)		Total heat flux (W/mm ²)	
	max	min	max	Min
Standard disc	212	146.07	0.90867	2.6247×10^{-6}
Modified disc 1	212	146.06	0.90922	1.6946×10^{-5}
Modified disc 2	212	210.19	0.021871	7.422×10^{-7}

Table:9

Disc type	Material -Carbon fiber reinforced carbon(CFC)					
	Static structural					
	Total deformation(mm)		Equivalent elastic strain(mm/mm)		Equivalent stress(MPa)	
	max	min	Max	max	min	Max
Standard disc	0.0015067	0	4.411×10^{-5}	2.4851×10^{-9}	8.818	0.00046268
Modified disc-1	0.002331	0	4.8259×10^{-5}	1.565×10^{-9}	9.645	0.00028067
Modified disc-2	0.0017459	0	4.6782×10^{-5}	1.9237×10^{-8}	9.3533	0.0019907

5.CONCLUSION

Hence, from above results heat-treated aluminium alloy has more heat flux has compared with carbon fiber reinforced carbon and steel alloy. On the basis of temperature, equivalent elastic strain and total deformation and equivalent stress carbon fiber reinforced carbon composite modified disc-2 has more efficient design as compared with standard and modified disc-1.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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