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Design & Analysis of Lightweight Disk Brake

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ABSTRACT

We cover the designing of the disk brake construction. The purpose of brake disk dimensioning and design is to confirm that a bike can be stopped safely under any possible driving conditions. Braking system design also needs to confirm that neither the disk itself nor any other component in its direct district is unprotected to excessive thermal loads. In this we have done two types of analysis i.e. thermal & structural.

Keywords: Disk Brake, Thermal Analysis, Structural Analysis, Composite material, lightweight

I. INTRODUCTION

At the IAA in Frankfurt in 1999, the carbon-ceramic brake disk had its world premiere. The use of the advanced material had transformed the brake technology. Now evaluation to the conventional gray cast iron brake disk to the carbon-ceramic brake disk evaluated round 50 per cent less reducing the unsprung mass by almost 20 kilograms. Further important advantages are, better brake response and vanishing data, high thermal stableness, excellent pedal feel, better-quality steering behaviour, high abrasion resistance and thus longer life time and the advantage of escaping almost completely brake dust. At first Porsche AG built the carbon-ceramic brake disk in 2001 into the 911 GT2 as series equipment. Meanwhile that time also further premium brands use the advantages of this advanced brake technology for more security and comfort. These are for example sports cars and luxury class limousines from Audi, Bentley, Bugatti and Lamborghini.

- The worldwide automobile brake system market is flooded with advanced, modern and cost effective brake system technologies.
- Canada (21.73%), Mexico (19.22%), Japan (16.33%), China (13.56%) and Brazil (6.54%) are the largest manufacturing countries of automobile brake systems in the world.
- The braking system establishes an essential part of an automobile. Failure of the automobile brake system at the time of emergency can lead to accidents, property damage or even death of an individual.
- In recent years, braking systems have undergone marvellous changes in terms of performance, technology, design and safety.
- Today, the brake system market is shelled with so many new and innovative technologies such as electronic brakes, anti-lock brakes, cooling brakes, disc brakes, drum brakes, hand brakes, power brakes, servo brakes and brake by wire.
- Utmost of the modern cars/bikes have disc brakes on the front wheels, and some have disc brakes on all four wheels in four wheeler and in rear wheel of bikes.
- This is the part of the brake system that does the actual work of stopping the cars and bikes.
- The disc brake is a device for slowing or stopping the rotation of a wheel. Repetitive braking of the vehicle leads to heat generation during each braking event.

II. METHODS AND MATERIAL

Creo is a family or suite of design software supporting product design for discrete manufacturers and is developed by PTC. The suite consists of apps, each delivering a distinct set of capabilities for a user role within product development.

In order to research relationship between stiffness, mass and design variables, common batch file is built by CREO.

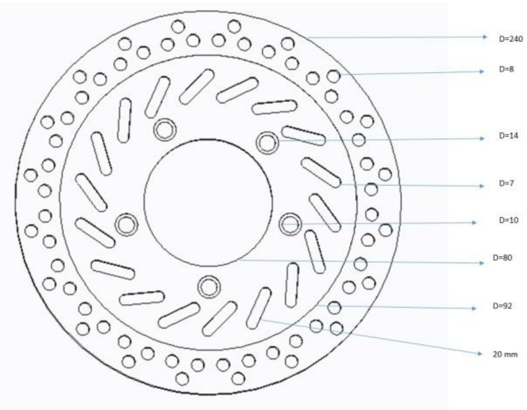

Figure 1: 2D Drawing of Disc

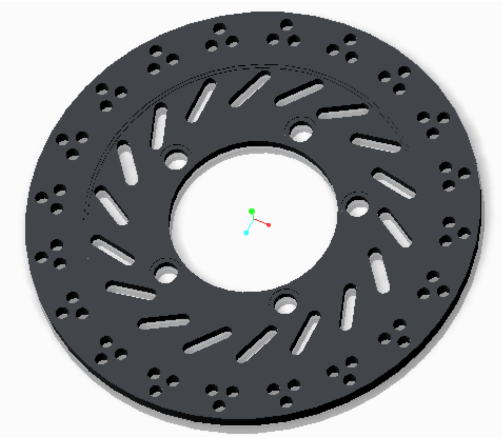
Figure 2: Disc Modeling in Creo

A different feature of carbon-ceramic brake disks is the ceramic composite material they are made from. Both the carbon-ceramic brake disk body and the friction layers applied to each side consist of carbon fiber-reinforced silicon carbide. The main matrix mechanisms are silicon carbide (SiC) and elemental silicon (Si). The reinforcement of the material is provided by carbon fibers (C). Silicon carbide, the main matrix component governs great hardness for the composite material. The carbon fibers make for high mechanical strength and provide the fracture toughness needed in technical applications. The resulting quasiductile properties of the ceramic composite material ensure its resistance to high thermal and mechanical load. Particular the low weight, the hardness, the steady characteristics also in case of high pressure and temperature, the resistance to thermal shock and the quasiductility provide long live time of the brake disk and avoid all problems resulting of loading, which are typical for the classic grey cast iron brake disks.

After studying research papers we selected one research paper "Design and Analysis of Disc Brake" & we use few data that are given below:

Disc Dimension : 240mm
Maximum Temperature : 350 °C
Maximum Pressure : 1Mpa
Normal force : 500 N
Heat flux : 33.585 kw/m2
Thermal Gradient : Heat Flux / Thermal Conductivity
= 33.582*103/40
= 839.63 k/m
Velocity = 27.77 m/s
Mass = 132 kg

Material Selected are

- Aluminum Alloy
- Cast Iron
- Gray Cast Iron
- Carbon Ceramic

In research paper we selected disc brake two wheelers model using in Ansys, done the Thermal and Structural Analysis to calculate the deflection, total heat flux, Frequency and temperature of disc brake model.

III. RESULTS AND DISCUSSION

A. *Analysis details Thermal Analysis*

Initial Condition

Table.1: Initial Condition for thermal analysis

Object Name	*Initial Temperature*
State	Fully Defined
Definition	
Initial Temperature	Uniform Temperature
Initial Temperature Value	350. °C

Aluminium Alloy

Table 2: Aluminium Alloy Properties

Density	2.77e-006 kg mm^-3
Coefficient of Thermal Expansion	2.3e-005 C^-1
Specific Heat	8.75e+005 mJ kg^-1 C^-1
Compressive Yield Strength MPa	280

Tensile Yield Strength MPa	280
Tensile Ultimate Strength MPa	310
Young's Modulus MPa	71000
Poisson's Ratio	0.33
Bulk Modulus MPa	69608
Shear Modulus MPa	26692

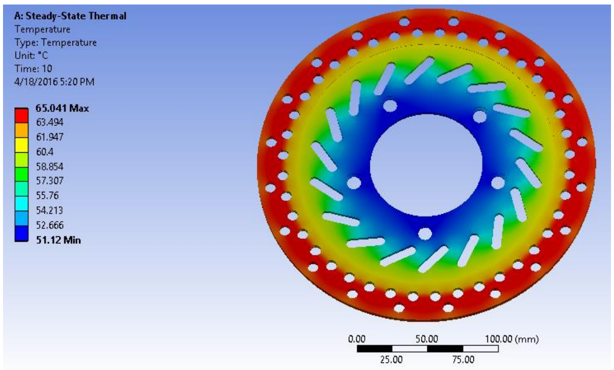

Figure 3: Temperature

Gray Cast Iron

Gray cast iron, is a type of cast iron that has a graphitic microstructure. It is named after the gray color of the fracture it forms, which is due to the presence of graphite.

Table 2: Gray Cast Iron Properties

Density	7.2e-006 kg mm^-3
Coefficient of Thermal Expansion	1.1e-005 C^-1
Specific Heat	4.47e+005 mJ kg^-1 C^-1
Thermal Conductivity	5.2e-002 W mm^-1 C^-1
Resistivity	9.6e-005 ohm mm
Compressive Ultimate Strength MPa	820
Tensile Ultimate Strength MPa	240
Young's Modulus MPa	1.1e+005
Poisson's Ratio	0.28
Bulk Modulus MPa	83333
Shear Modulus MPa	42969

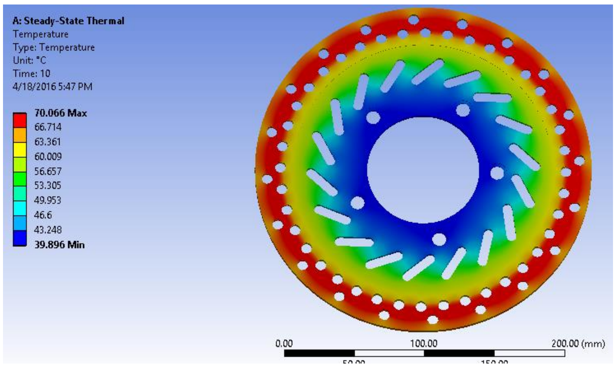

Figure 4: Temperature

Cast Iron

Table.3: Cast Iron Properties

Density	5.536e-006 kg mm^-3
Thermal Conductivity	1.13e-002 W mm^-1 C^-1
Tensile Ultimate Strength MPa	90.321
Tensile Yield Strength MPa	65.5
Compressive Yield Strength MPa	330.95
Young's Modulus MPa	62100
Poisson's Ratio	0.24
Bulk Modulus MPa	39808
Shear Modulus MPa	25040

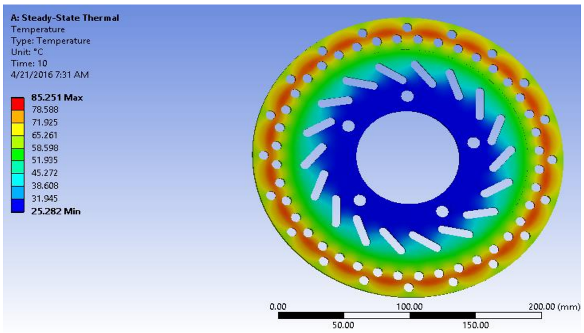

Figure 5: Temperature

Carbon Ceramic

Table 4: Carbon Ceramic Properties

Density	2.e-006 kg mm^-3
Specific Heat	800 mJ kg^-1 C^-1
Thermal Conductivity	4.e-002 W mm^-1 C^-1
Tensile Ultimate Strength	20

MPa	
Coefficient of Thermal Expansion	2.6 C^-1
Tensile Yield Strength MPa	310
Compressive Yield Strength MPa	500
Young's Modulus MPa	95000
Poisson's Ratio	0.1
Bulk Modulus MPa	39583
Shear Modulus MPa	43182

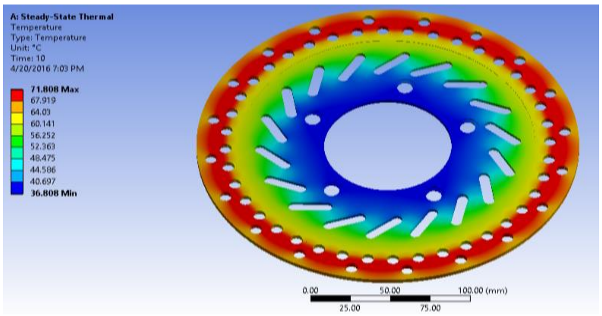

Figure 6: Temperature

*B. **Analysis details Static Structural Analysis***

In this analysis the general information is given below & the analysis is done according to provided data.

Force : 500N

Temperature : 40 °C

Rotational velocity : 22.77 m/s @ 1000 rpm

Analysis Settings Step is Specify "Step Controls"

Aluminum Alloy

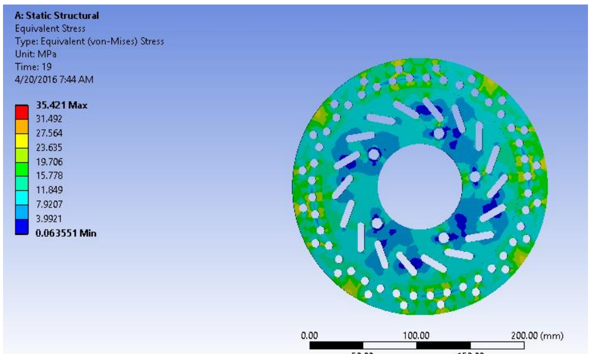

Figure 7: Equivalent stress

Gray Cast Iron

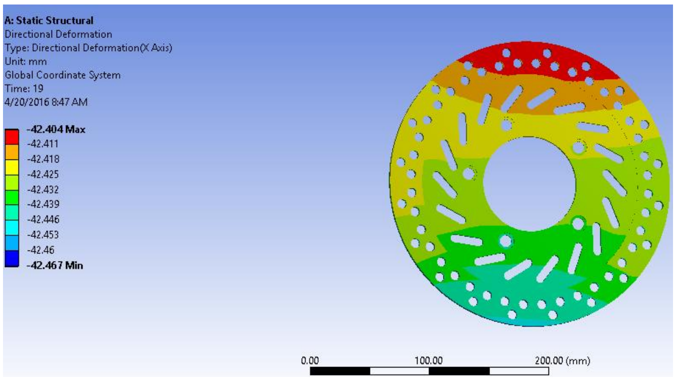

Figure 10: Directional Deformation

Cast Iron

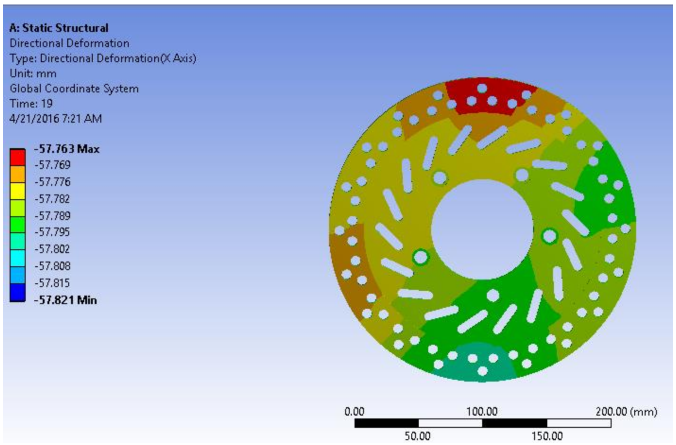

Figure 8: Directional Deformation

Carbon ceremic

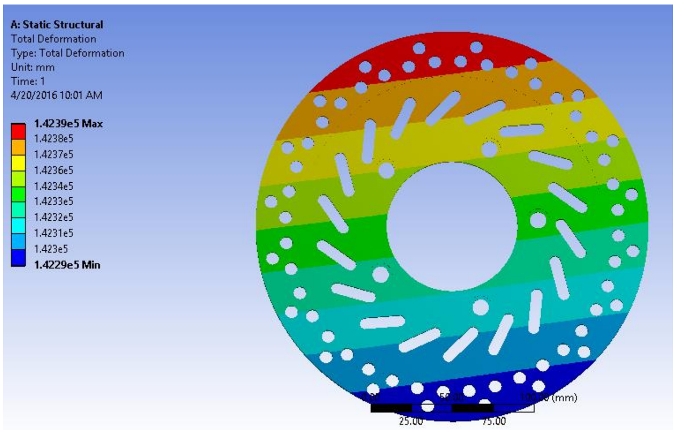

Figure 9: Total Deformation

IV. CONCLUSION

- ✓ As per our design and comparison we observe that Carbon ceramic disc brake is lighter than gray cast iron disc brake.

- ✓ We have decrease approximate 75% weight by using carbon ceramic and its heat generation in disc plate.
- ✓ The noise & vibration in braking will be small as parallel to other convention brake material like cast iron, steel etc.
- ✓ We observe that heat flux is more in cast iron during analysis and weight is also more.
- ✓ Carbon Ceramic Brakes have many benefits over outdated cast iron brakes.
- ✓ From 50% or more in unsprang-weight reduction to faster stopping distances.
- ✓ Carbon ceramic brakes can last about four times longer than cast iron rotors.

V. Comparing Result

Table 5 : Mass & Volume

Materials	**Properties**	
Aluminum Alloy	Volume	Mass
	1.1512e+005 mm³	0.31889 kg
Gray Cast Iron	1.1512e+005 mm³	0.82889 kg
Cast Iron	1.1512e+005 mm³	0.63732 kg
Carbon Ceremic	1.1512e+005 mm³	0.23025 kg

Table 6: Static Structural Analysis

Materials	***Temperature***		***Thermal Error***	
Aluminum Alloy	Minimum	Maximum	Minimum	Maximum
	51.12 °C	65.041 °C	1.1001e-006	11.832
Gray Cast Iron	39.896 °C	70.066 °C	1.0024e-006	28.845
Cast Iron	25.282 °C	85.251 °C	2.8596e-007	150.37
Carbon Ceremic	36.808 °C	71.808 °C	8.7754e-007	38.281

Table. 7: Steady State thermal Results

Materials	**Minimum**	**Maximum**	**Time(s)**
Aluminum Alloy	7.9026, 7.9066, 7.905	15	10,11,13
Gray Cast Iron	6.9341, 6.9425, 6.9427	15	10,11,15
Cast Iron	1.8862, 1.8842	15	10,13
Carbon Ceramic	0.29645 - 0.29789	15	10 - 12

Table 8. Safety factor

Materials	***Total Deformation***		***Directional Deformation***		***Equivalent Elastic Strain***		***Equivalent Stress***	
Aluminum Alloy	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
	1.9045e+005 mm	1.9044e+005 mm	-25.35 mm	-25.241 mm	4.2858e-006 mm/mm	5.0342e-004 mm/mm	6.3551e-002 MPa	35.421 MPa
Gray Cast Iron	1.2292e+005 mm	1.2292e+005 mm	-42.467 mm	-42.404 mm	2.6619e-006 mm/mm	3.1725e-004 mm/mm	0.14271 MPa	34.569 MPa
Cast Iron	2.1774e+005 mm	2.1774e+005 mm	-57.821 mm	-57.763 mm	5.128e-006 mm/mm	5.6513e-004 mm/mm	0.16207 MPa	34.764 MPa
Carbon Ceramic	*1.423e+005 mm*	*1.4257e+005 mm*	*-5629.7 mm*	*5602.4 mm*	*2.7619e-006 mm/mm*	*1.1762e-002 mm/mm*	*0.10261 MPa*	*1040.7 MPa*

VI. Future Scope/Benefits

- ✓ Carbon ceramic offers important benefits in terms of performance in both wet and dry conditions weight, comfort, corrosion resistance, durability and advanced appeal.
- ✓ Carbon ceramic brakes produce fewer noise during braking.
- ✓ Currently it is used in Sports car & many commercial vehicle.
- ✓ Carbon ceramic which use disc brake works more professionally, which can help to decrease the accident that may happen in each day.

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