Design & Analysis of High Performance, Minimum Weight Automotive Carbon Ceramic Disc Brake

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Abstract- *Here we have design a disc brake plate and we have used a carbon ceramic material. The purpose of using carbon ceramic for disc plate material is that we want to observe that this material is better for future scope. And after doing analysis we found that carbon ceramic bake has many advantages over cast iron, or other material. For finding the better result we have done thermal, model, static structural analysis.*

Keywords- Disc Brake, Thermal Analysis, Structural Analysis, Modal Analysis, Composite material, lightweight.

I. INTRODUCTION

The secret of the advantages of the carbon-ceramic brake disc is the exclusive manufacture procedure. The production process includes preparation of the fiber mixture, the production process for the disc body and the bell mounting as well as the ultimate machining of the assembled brake disc. The entire production process is examined with various tests and ends with one final testing. The production procedure of the ceramic brake body endures with a preform forced with binding resin to a so called green body which will be converted in the ceramic component by carbonizing at 900 °C and siliconizing at 1700 °C in high vacuum. The compound feature of the manufacturing procedure is the use of the “lost core” technology a plastics matrix which defines the design of the cooling vane geometry and which burns out without remains at carbonizing as well as the different fiber components of the brake disc body, the friction layers on the ring exterior side and the point-shaped abrasion indicators which are integrated into the friction layer.

A carbon-ceramic brake is developed in three main stages to match a car´s particular layout numerical modeling, the construction and testing of prototypes, and testing on an actual car.

The use of the advanced material had transformed the brake technology. Important advantages are, better brake response and vanishing data, high thermal stableness, excellent pedal feel, better-quality steering behavior, 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 disc 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 marvelous 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.

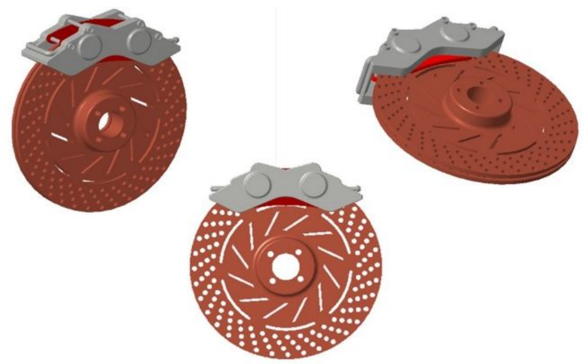


Fig no. 1 Design of Disc Brake

Material Data for analysis

Table 1 Asbestos Detail

Density	7.2e-015 kg mm^-3
Young's Modulus Mpa	0.11
Poisson's Ratio	0.28
Bulk Modulus Mpa	8.3333e-002
Shear Modulus Mpa	4.2969e-002

Table 2 Carbon Ceremic Detail

Density	2.e-006 kg mm^-3
Specific Heat	800 mJ kg^-1 C^-1
Isotropic Thermal Conductivity	4.e-002 W mm^-1 C^-1
Isotropic Secant Coefficient of Thermal Expansion	2.6 C^-1
Tensile Ultimate Strength Mpa	20
Young's Modulus Mpa	95000
Poisson's Ratio	0.1
Bulk Modulus Mpa	39583
Shear Modulus Mpa	43182
Zero-Thermal-Strain Reference Temperature C	350
Tensile Yield Strength Mpa	310
[illegible]	[illegible]

A different feature of carbon-ceramic brake discs is the ceramic composite material they are made from. Both the carbon-ceramic brake disc 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. 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 disc and avoid all problems resulting of loading, which are typical for the classic grey cast iron brake discs.

In this paper we selected and designed disc brake plate model using in Creo & different type of analysis such as thermal, structural, model analysis done by sing Ansys to calculate the deflection, total heat flux, Frequency and temperature of disc brake model.

III. RESULTS AND DISCUSSION

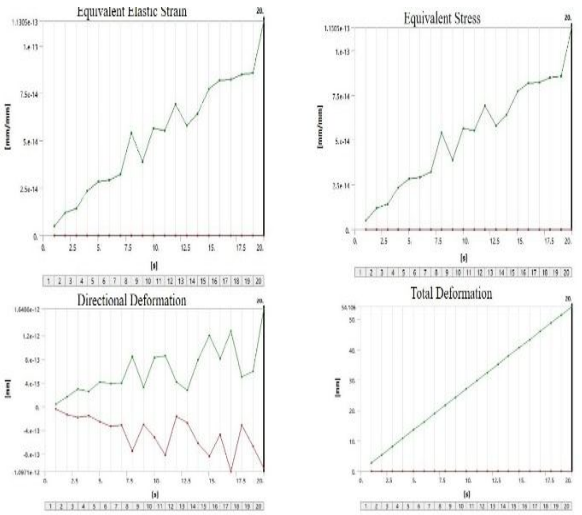
Static Analysis Detail

In this analysis the general information is given below &

The analysis is done according to provided data. Analysis Settings Step is Specify "Step Controls"

Table 3 Static analysis detail

Force	500N
Temperature	38 °C
Rotational velocity	22.77 m/s @ 1000 rpm
Maximum Pressure	1Mpa
Number of Steps	20
Tolerance Value	1.1386 mm
Transition Ratio	0.270



Graph 1 Static analysis (Von Mises Stress, Deformation & Strain)

The graph 1 and fig. no 2 show the result of Static analysis which include Equivalent elastic strain, equivalent stress, directional deformation and total deformation, the result data is in table no 5.

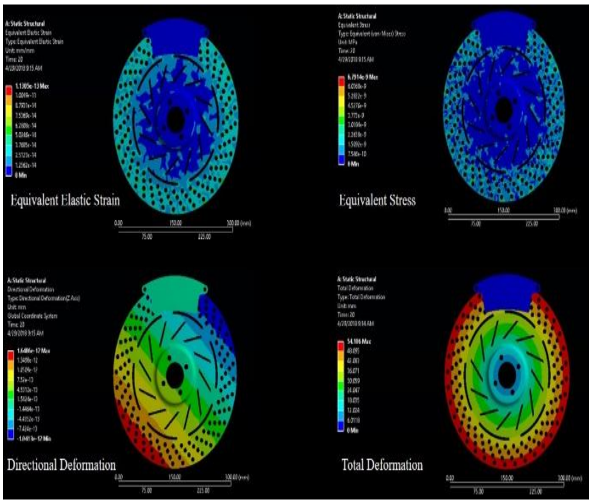
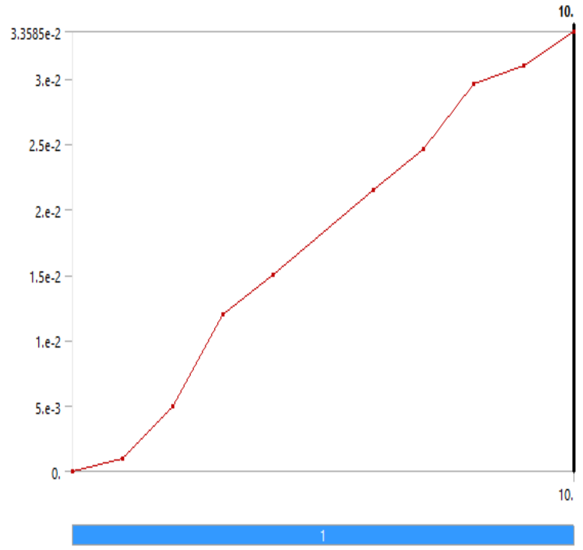


Fig No. 2 Static analysis (Von Mises Stress, Deformation & Strain)

Steady State Thermal

Table 4 Steady State thermal

Thermal Gradient	Heat Flux / Thermal Conductivity	
	33.582*103/40	
	839.63 k/m	
Maximum Temperature	350 °C	
Velocity	99.972 kmph	



Graph 2 Heat Flux

Model Analysis

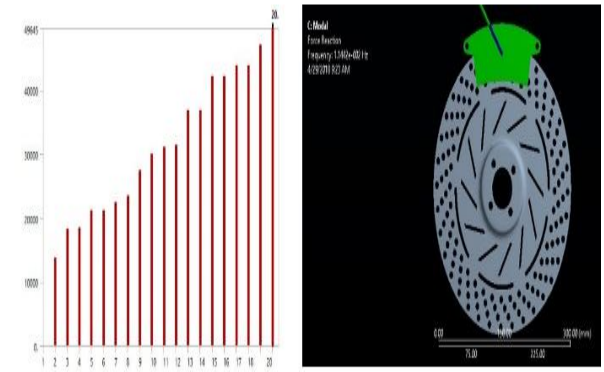


Fig no. 3 Model Analysis

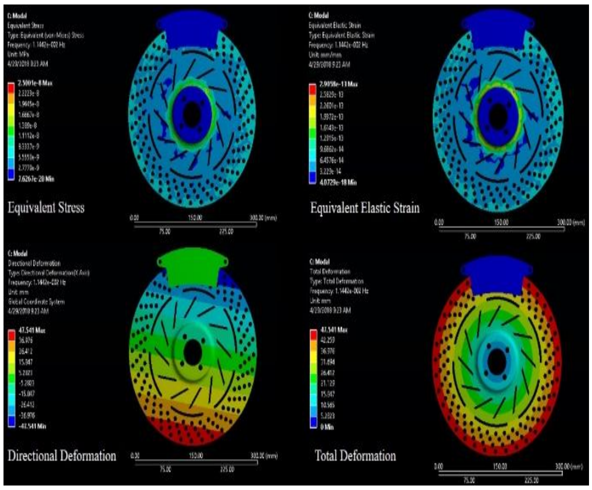


Fig no. 4 Model Analysis (Von Mises Stress, Deformation & Strain)

V. CONCLUSION

- As per our design and comparison we observe that Carbon ceramic disc brake is lighter than other disc brake material.
- 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.
- The weight is calculated here 1.1579 kg.

VI. FUTURE SCOPE

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.

Table 5:- Results

Analysis Type	*Total Deformation*		*Directional Deformation*		*Equivalent Elastic Strain*		*Equivalent Stress*	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximu m
Static Structural	0. mm	4.106 mm	-1.0413e-012 mm	1.6486e-012 mm	0. mm/mm	1.1305e-013 mm/mm	3.2161e-010 MPa	6.7914e-009 MPa
Modal Analysis	0. mm	47.5 41 mm	-47.541 mm	47.5 41 mm	4.0729e-018 mm/mm	2.9058e-013 mm/mm	7.6267e-020 MPa	2.5001e-008 MPa
Safety factor	*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*
Steady State Thermal	*Temperature*	*Minimum*	36.808 °C					
		Maximum	71.808 °C					
	Thermal error	*Minimum*	8.7754e-007					
		Maximum	38.281					
Steady State thermal Results	Min	0.29645 -0.29789						
	Max	15						
	Time(s)	10 - 12						
Weight	1.1579 kg							

REFERENCES

[1] Darle W.Dudley, 1954, Hand book of practical gear design Alec strokes, 1970, High performance of gear design.

[2] Maitra, G.M, 2004, Hand Book of Gear Design, TataMcGrawHill, New Delhi.sign

[3] Chogdu Cho and Sooick Ahn, "Thermo-Elastic Analysis for Chattering Phenomenon of Automotive Disk Brake", 'KSME International Journal', 2001,Vol-15, pp 569-579.

[4] Guru Murthy Nathi, K. Gowtham and Satish Reddy, "Coupled Structual / Thermal Analysis of Disc Brake", IJRET 2012, Vol.1, pp.539-553.

[5] V. M. Thilak , R. Krishnara Deepan & R.Palani ,"Transient Thermal and Structural Analysis of the Rotor Disc of Disc Brake ", International Journal of Scientific & Engineering Research Volume 2, Issue 8, August-2011 Issn 2229-551.

[6] Mehul Rawal*, Manish Daiya "Design & Analysis of Lightweight Disk Brake "IJSRST | Volume 3 | Issue 6

[7] D.L. Schmidt, K.E. Davidson, L.S. Theibert, Unique applications of carbon/carbon compositen materials, part 1. SAMPE J. 25, 3 (1999)

[8] D.J. Holt, Aircraft braking systems. Aerospace Eng. 1993 Concorde brakes by DUNLOP are C/C. Aircraft Eng. 48, 9 (1976)

[9] D. Neudeck, A. Wüllner, Bremsen mit nichtmetallischen Bremsscheiben, in

[10] Bremsenhandbuch, ed. by B. Breuer, K.H. Bill (Vieweg & Teubner/GWV Fachverlage,

[11] Wiesbaden, Germany, 2006) Deutsches Institut für Normung, Gießereiwesen Gusseisen mit Lamellengraphit. DIN EN 1561 (Beuth Verlag, Berlin, Germany, 1997)

[12] Duralcan Composites for Gravity Castings (Data Sheet Duralcan, San Diego, CA, USA, 1992)

[13] Lanxide, ASM Al-342, Lanxide, 91-X-1060-30P-T6 (aluminum alloy-matrix composite).

[14] Alloy Digest (ASM International, Materials Park, OH, USA, AI-342, 2002)

[15] P. Morgan, Carbon Fibers and Their Composites, 1st edn. (CRC Press, Boca Raton, FL, USA, 2005) SGL Group, SIGRASIC 6010 GNJ-Faserverstärkte Keramik für Bremsscheiben von SGL carbon (Data Sheet SGL Technik, Meitingen, Germany, 1999).