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Analysis of Brake Rotor Material

Aadil A. A. Chicktay[1], Shreyash Bhoir[2], Pradhyumn Kokane[3], Darshan Gangar[4]
[1,2,3,4]*Student, Department of Automobile Engineering, Saraswati College of Engineering, Kharghar, India*

***Abstract*—Every year many Car manufacturers invest a lot of money in the research and development in the car's performance, comfort and safety. One of the most important themes about car manufacturing is safety. When we talk about car reliability and safety, the first thing comes in our mind is braking systems. Despite the great performance, every car must be equipped with appropriate Braking system Braking system in every vehicle is made up of many components. As automobile engineers and having avid interest in cars, we have chosen to investigate two different material brake discs namely 'Cast iron Discs' and 'Carbon ceramic discs' or rotors in the paper. It is really important to learn about this key component 'Brake discs' The aim of the project is to understand the usage of Cast iron and Carbon ceramic brake discs in different conditions and where should we use either of the type in different types of vehicles. The purpose of the project is to identify the different type of Materials used in the manufacturing of Brake discs and their application in various scenarios. This project involves discovering from various research papers, how Carbon Ceramic and Cast iron discs hold good in their respective cases. This has been done by carefully examining the research papers. We have concentrated on 2 materials namely, Carbon Ceramic and Cast iron. We have reviewed the research paper on 'Carbon ceramic discs' in which we come upon the fact that these Materials prove to be solid and good for High end vehicles which attain high speeds. These discs are light and also provide good stopping power with great heat dissipation. Along with this, We have reviewed the research paper on 'Cast iron discs' in which, we come to know that cast iron discs are Economical and are used on almost every passenger vehicle where high performing brake discs are not simple needed as they don't attain high speeds. The aim of this project is to differentiate between the Carbon ceramic discs and Cast iron discs and also to learn about their usage.**

***Index Terms*—Cast iron rotor thermal analysis, Effect of Heat Flux and temperature on disc, Carbon Ceramic Rotor introduction, Production, Significance of Carbon Ceramic based brake discs, Braking Curve under certain scenarios.**

I. INTRODUCTION

At present scenario, commercially used materials for disc brake rotor are Cast Iron, Reinforced Carbon–Carbon or Ceramic matrix composites etc. In the present study Gray Cast Iron and stainless steel are two chosen for analysis. Despite the great performance, every car must be equipped with appropriate braking system. Today almost every super sport or sport car is supplied with new types of brakes called carbon-ceramic. It was taken from aerospace application and the technology was manufactured and designed for super sports or very powerful cars. Against cast iron discs' carbon-ceramic ones provide extraordinary advantages that results directly in cars performance improvement. These discs meet the needs of performance excellence, driving comfort and safety.

II. CAST IRON

A. *Steady-State Thermal Analysis*

A steady-state thermal analysis calculates the consequences of steady thermal loads on the element. Thermal analysis is to observe temperatures, thermal gradients, heat flow rates, and heat fluxes in an object that are caused by loads that don't & vary over time. Heat flux and heat generated in various cases considered are tabulated in the table for easy reference.

TABLE I
HEAT FLUX AND HEAT GENERATED IN VARIOUS CASES

	Heat generation (Q in joules)	Heat Flux (q in kW/m^2)
Existing disc (Stainless Steel)	5670	82.790
Existing disc (Gray Cast Iron)	7032	66.705
Modified Disc (5mm, Stainless Steel)	5040	63
Modified Disc (5mm, Gray Cast Iron)	70587.77	88.327

B. *Effect of Temperature and Heat Flux on Modified Disc*

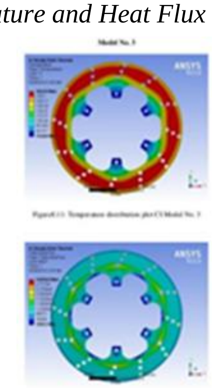

Fig. 1. Heat flux plot C1 model no. 3

Effect of temperature on modified disc of grey cast iron with 5mm thickness, the maximum temperature of 563.62 °C is

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developed at brake contact point that is at end of rotor and minimum temperature of 94.806 °C is at clamping holes. Red and blue color indicates maximum and minimum temperatures as shown in below figure Effect of heat flux on modified disc of grey cast iron with 5 mm thickness, the maximum heat flux of 1.0298 W/mm^2 is generated at brake pad contact point and minimum heat flux of 0.0023396 W/mm^2. Red and blue color in the figure indicates maximum and minimum heat flux values respectively.

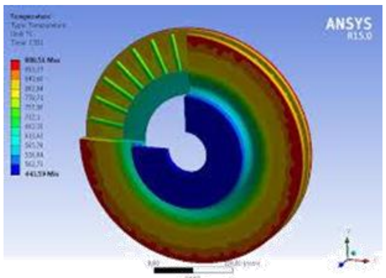

Fig. 2. Maximum and minimum heat flux

III. Results and Discussion

Thermal analysis is performed for heat flux and temperature. Heat flux i.e. heat generated per seconds per unit area and convective heat transfer coefficient are applied to existing and modified disc brake rotor as boundary conditions. After applying boundary conditions, as a result temperature and heat loss per unit area are calculated for best material suitable for disc brake rotor. Following tabular column shows the structural and thermal analysis results:

TABLE I
Structural and Thermal Analysis

	Material	Material Deformation (mm)	Von mises stress (MPa)	Heat Generation (J)	Heat flux (W/mm2)	Temperature (°C)
Existing disc/Reference disc	Stainless steel	0.0016866	11.982	5670	0.5383	622.76
	Grey cast iron	0.0029268	12.082	7032	0.92713	554.07
Modified disc (5mm thick)	Stainless steel	0.0019102	12.629	5040	0.47389	547.35
	Grey cast iron	0.0032829	11.563	7058.77	1.0298	563.62

IV. Carbon Ceramic

A. Brake Production

Carbon-Ceramic brakes offer high performance braking under different conditions, wear relatively over time and are light weight compared to theother material brakes.These are made from Ceramic fibres, Filler materials, bonding agents and they may also have small amounts of Copper fibres reinforced in itself Because of it and Ceramic nature, they dissipate the heat pretty well under few hard stops and produce very less dust which does not get adhered.

B. Advantages of Carbon-Ceramic Brake Discs

There are many advantages of this kind of a setup:

1) Reduced weight: These brakes are approximately 50% lighter than the cast iron brakes of the same size due to lower density. This indeed improves the handling, vehicle dynamics and cornering capabilities.
2) Great hardness and reduced wear rate: The structure of the Ceramic based discs is more solid. This provides longer life and reduced wear and tear .Compared with steel ones, this material lasts four times longer.
3) Deformation resistance: At high temperatures, carbon ceramic materials are more resistant to deformation or warping because of their high thermal stability values (1350° for carbon ceramic vs. 700°C for cast iron)

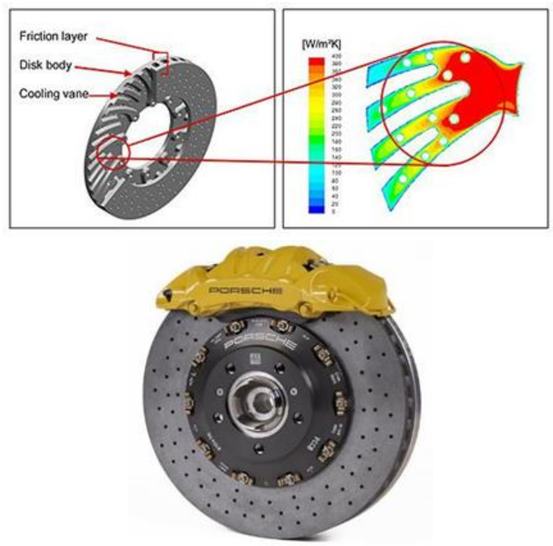

Fig. 3. Brake

C. Disadvantages of Carbon-Ceramic Brake Discs

1) High initial cost: Carbon ceramic brake discs are very expensive compared to the iron based discs. The consumer must decide on his own whether it is worth investing or not. The fact though, is that the Carbon ceramic brake discs outlive the ones based on iron.
2) Higher operating temperatures: There is less braking feel during the first part of travel, especially when the ceramic rotors are cold. The reason for this is that the optimal operating temperature of the carbon materials is much higher than those found in normal brakes.
3) Limited brake pad selection - Carbon ceramic is not compatible with most brake pads that are intended for cast iron rotors. Due to the different frictional and thermal properties of iron and ceramic discs it is important to use a brake pad compound that has been specifically developed for ceramic brake discs.

D. Material Structure of Carbon-Ceramic Brakes

A special feature of carbon-ceramic brake discs is the ceramic composite material they are made from. The carbon-ceramic brake disc body and the friction layers applied to each side consist of carbon fiber-reinforced silicon carbide. Silicon carbide (SiC) and elemental silicon (Si) are the main matrix components. The reinforcement of the material is provided by carbon fibers (C). The main matrix component silicon carbide governs great hardness for the composite material. The carbon fibers assent to high mechanical strength and provide the fracture toughness needed in technical applications. The resulting quasi-ductile properties of the ceramic composite material ensure its resistance to high thermal and mechanical load.

E. Braking Curves on Different Conditions

The first braking coefficient curves of C/C-SiC composites under dry and wet Conditions are shown in Fig. It seems that two friction coefficient curves are basic consistent, although the curve under dry condition is rougher. The two braking coefficient curves arise gradually in the beginning period of the braking, appearing the so-called “first peak” phenomenon. Afterward, the coefficient of friction reduces and the curves tend to change smoothly. At the end of the braking, the COF starts to increase again.

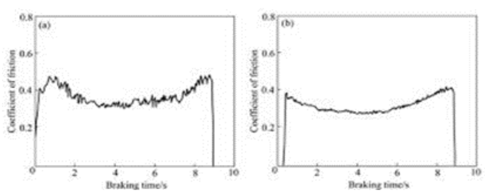

Fig. 4. Braking curves

V. CONCLUSION

The influence of dry and wet conditions on the tribological characteristics of the C/C- SiC composites was ascertained. Under dry condition, C/C-SiC braking composites show superior tribological characteristics, including high coefficient of friction (0.38), good abrasive resistance (thickness loss is 1.10 μm per cycle) and steady breaking. The main wear mechanism is plastic deformation and abrasion. Under wet condition, frictional films form on the worn surface. The coefficient of friction (0.35) could maintain mostly, and the thickness loss (0.70 μm per cycle) reduces to a certain extent .After a detailed study of various Research papers, there's a lot to conclude. Carbon-Ceramic based discs are mainly used in high performance vehicles only. With extreme temperatures, a carbon-ceramic brake disc is about twice as resistant as a conventional steel brake disc. In addition, these brakes are not only more resistant to heat: Because the special carbon-ceramic brake material is friction-wear-free and oxidation-resistant (resistant to rust or road salt), automakers can provide durability and durability up to 300,000 to 350,000 kilometers. They have much superior Specifications than the Cast-iron Discs but unfortunately the production of Carbon-Ceramic discs is not Economical. This is a big hindrance for a manufacturer to equip their Passenger vehicles with such type of High end Discs. Cast iron rotors are heavy and cheap. They don't provide characteristics as that of Carbon ceramic rotors but they offer good friction coefficient, enough for a mid-sized passenger vehicle. On the other hand, Manufacturers have been working on ways of making aluminum work by tweaking the alloys and bonding aluminum cores to steel outer discs in an effort to keep the rotors together. There have been some significant advancements in brakes, making them universally functional for non-motorcycle applications, but other materials are making inroads as well. Carbon-ceramic and carbon-carbon brake rotors offer all the weight savings and benefits of aluminum, but can withstand higher temperatures than steel. Granted, these materials also cost 10 times as much, so aluminum may yet have a serious future in automotive performance and heavy-vehicle applications. As we see, there's a lot of development needed to be done in terms of Rotors. Aluminium, composite materials have a good future as Key materials in the production of Brake discs given that proper Research and development is carried out. Automobile Industry needs a blend of the two, Carbon-Ceramic and Cast iron Discs. There needs to be a research done on Composite material Brake rotors.

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