DESIGN AND ANALYSIS OF DISC ROTOR FOR FORMULA STUDENT VEHICLE

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ABSTRACT

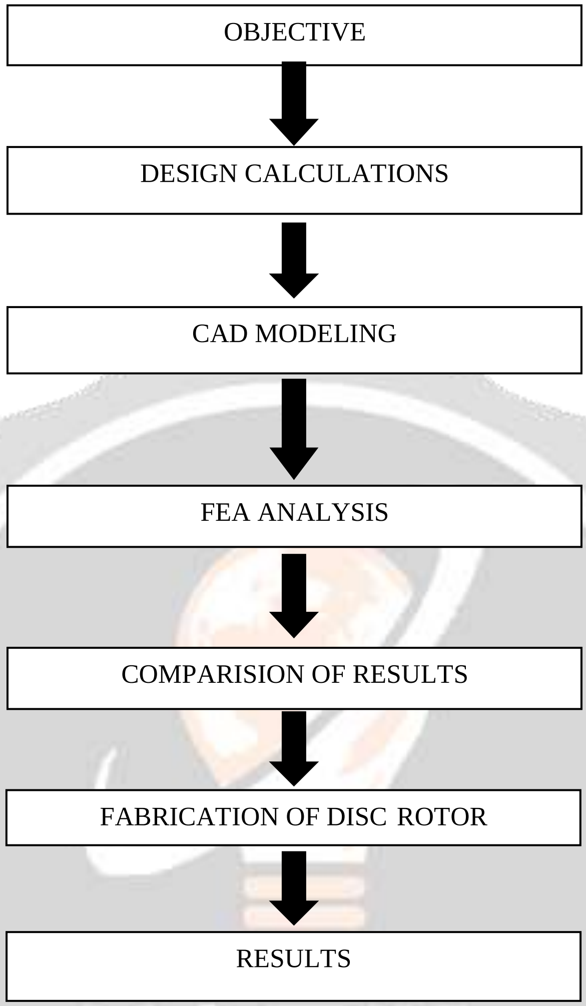
A brake is a mechanical device that inhibits motion by either slowing down, stopping, or preventing the motion of an object in motion. The two main types of brakes are drum brakes and disc brakes. This study includes the Brake Disc/Rotor Design and Analysis for FSAE/SAE SUPRA. Weight, wheelbase, tyre size, and other factors common to Formula Student vehicles are taken into account when designing the disc. Four typical profiles are available when choosing a type of brake disc: solid, drilled, slotted, and combination (drilled and slotted). Heat Flux, a disc's mass, stress-induced deformation, and a common engineering material are used as the deciding factors. By changing a specified list of engineering materials as follows, a comparative analysis of Rotor is demonstrated: Cast iron, EN-19, SS-304

Keyword: *FSAE, Standard parameters, Brake Efficiency, Structural and Thermal analysis and comparative result.*

1. INTRODUCTION

Kinetic energy is a property of moving objects, and its value varies with the mass and speed of the object. The majority of brakes primarily involve friction between two surfaces that are pressed together to modify the kinetic energy. The energy of the moving object is turned into heat, notwithstanding the possibility of using alternate energy conversion methods. The friction material in the brake pads is compressed against the surface of the rotating braking disc when the brake pedal is pushed or applied. Friction is produced as a result of this contact, enabling the vehicle to stop or slow down. The main purposes of brake systems are to hold a car when parking and to keep it moving when necessary. To achieve this, we must validate the brake system design based on calculations made using the vehicle's specifications. The principle behind the brake system is that more torque should be produced when braking than is necessary. When the driver applies force, it is directly passed through the pedal assembly, which amplifies the force by employing simple leverage. The generated force is then divided using a bias or balancing bar, allowing for varying amounts of force to be directed to the front and rear brakes. The balancing bar has a master cylinder attached to each end, one of which controls the front brakes and the other the rear brakes. The master cylinders are loaded with braking fluid from a reservoir, which causes hydraulic pressure to operate them. Through hydraulic lines, calipers that physically grip the brake rotor at each of the four wheels are supplied the pressure generated in the master cylinder.

1.1 METHODOLOGY



1.2 BRAKE CALIPER AND MASTER CYLINDER SELECTION

The most important component of the braking system are the calipers. It is merely a clamping mechanism that prevents the brake disc from moving by causing friction between the brake pads, which eventually brings the car to a complete stop. The effectiveness of the braking mechanism is directly impacted by the caliper choice. The characteristics such as needed braking force, required piston area, rim and space restrictions, cost concerns, and availability are taken into account when choosing a lightweight and stiff brake caliper. Due to their outstanding performance, lightweight construction, and accessibility, Wilwood GP 200 brake calipers were our choice. Wilwood GP 200 is a floating caliper. Their stainless steel pistons, forged aluminum bodies, and two-piston design offer dependable stopping power and increased durability. Brake parts like the Wilwood 0.625 master cylinder are made for high-performance uses like racing. It has a 0.625-inch bore diameter and a significant amount of stopping force. Because of its small size, the master cylinder is perfect for cars with small engine compartments. It is made with premium components to ensure durability and dependability in harsh environments. The Wilwood 0.625 master cylinder is compatible with most braking fluids and can be used with a number of brake systems.

PISTON COUNT	PISTON TYPE	PISTON AREA	ROTOR DIAMETER	ROTOR WIDTH	BORE SIZE	WEIGHT	PAD AREA
2	Stainless steel	31.242 mm^2	279.4 mm	6.35 mm	31.8 mm	408.233 gram	1180.643 mm^2

Table -1: Specifications of Wilwood GP 200 caliper

2. BRAKE TORQUE CALCULATIONS

	STATIC CONDITION	
1.	Overall weight of the car (Kg)	280
2.	Wheelbase (mm)	1550
3.	Decelaration (m/s^2)	4
4.	Horizontal distance from CG to front axle (mm)	806
5.	Horizontal distance from CG to rear axle (mm)	744
6	Wheel diameter (inches)	13
7.	Disc rotor (outer diameter in mm)	183.5
7.	Coefficient of friction	1.5

Table -2: The table below shows the car's features when it is static.

2.1 AVAILABLE TORQUE VALUES

The force that brakes exert to a vehicle's wheels to slow or stop their spin is referred to as brake torque. It is a vital element in establishing a vehicle's braking performance because it influences how efficiently and safely the vehicle can decelerate. The friction that occurs between the brake rotor (or drum) and the brake pads produces the brake torque, which is inversely proportional to the force supplied to the brake pedal. Generally speaking, a vehicle's braking power increases with increasing brake torque.

S.No	Available Torque	Front	Rear
1.	Dynamic axle loads (N)	1504.182	1394.31
2.	Braking Force (N) before wheel lock	2256.273	2091.495
3.	Force while Braking (N)	1128.1365	1045.75
4.	Required Braking Torque (N mm)	$2.29*10^5$	$2.12*10^5$

Table -3: Available Torque values

2.2 REQUIRED TORQUE VALUES

The below calculations are used to find if the components selected can produce higher braking torque than the required torque.

1.	Force on Master cylinder (N)	1373.4
2.	Pressure developed by the master cylinder (N/mm^2)	6.94
3.	Clamping force (N)	11014.5
4.	Frictional force (N)	3855.075
5.	Actual braking Torque (N mm)	$2.91*10^5$

Table -4: Required torque values

As a result, the vehicle can reach its peak deceleration and reduce its speed in a brief period of time because the actual braking torque produced by the brake components chosen is more than the required braking torque.

3. CAD MODEL OF DISC ROTOR

The calculations and requirements for the wheel hub and knuckle of the Willhood calliper GP 200 led us to choose a disc rotor of thickness with an outer radius of 183.5 mm and an inner radius of 149.5 m as the necessary measurements for designing our customized rotor. Drilled & slotted profile disc is designed. The drilled holes and slots help with dissipate heat and gases that can accumulate during hard braking, lowering the possibility of brake fade and enhancing overall braking performance. In addition, they increase the durability of the brake pads and aid to lessen brake dust. Additionally, because water can drain from the brake surface more effectively, the drilled and slotted profile improves grip and stopping ability in wet weather conditions.

Chart -1: Drilled & slotted disc rotor profile

3.1 SELECTED MATERIALS

We settled on EN-19, SS-304, and cast iron. Cast iron is a frequently used material for disc brake rotors because of its high heat conductivity, high wear resistance, and affordable cost. EN-19 (a high strength alloy steel) is used for high-performance applications needing additional mechanical capabilities, such as race cars and high-performance vehicles. SS-304 (stainless steel) is used when corrosion resistance is essential, such as in coastal settings. Each material has unique features and is selected based on the specific needs of the application.

4. FINITE ELEMENT ANALYSIS

With the use of FEA, it is possible to predict how a part or assembly will react to different applied loads and boundary conditions. The product is assessed, and the loads and boundary conditions are applied to find the best design. For the brake disc, static structural analysis is carried out to ensure that the assembly and its attachment are robust enough to withstand the stresses. Steady state thermal analysis is also performed on brake discs because they are subject to thermal loads. The study is performed using ANSYS Workbench 19.2.

4.1 STATIC STRUCTURAL AND STEADY STATE THERMAL ANALYSIS

Total deformation, equivalent von-Mess stress, and safety factor are all examined. The results will be more accurate the finer the mesh. For braking discs, a 5 mm element mesh is produced. Clamping force on both sides of the brake disc where the pads would clamp the disc, braking torque in the opposite direction of the rotation of the disc, and rotational velocity of the disc are the boundary conditions that must be imposed. Where the floaters will install the disc and carrier, fixed supports are offered. The model is solved when these boundary conditions have been applied

The braking mechanism operates on the basis of friction, which produces a tremendous amount of heat. For brakes to function effectively, the heat that is produced must to be dissipated uniformly. In steady state thermal analysis, the model is solved under steady state thermal loading for temperature change and heat flux. It generates a 5 mm mesh.

Heat flux, the surrounding temperature, the film coefficient, and the maximum temperature are the initial boundary conditions. The results of these two analyses, which were carried out for the chosen cast iron disc rotors EN-19 and SS-304, are shown below. These analyses were completed using boundary conditions for steady state thermal analysis.

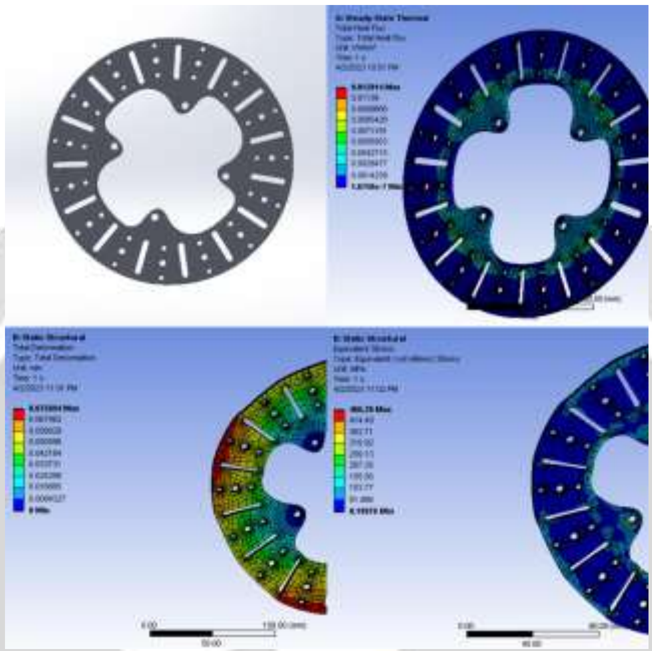


Fig -1: SS-304

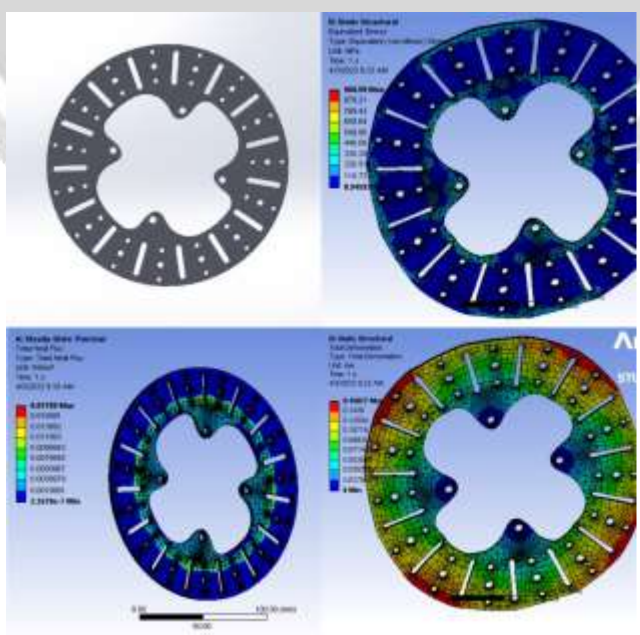


Fig -2: EN-19

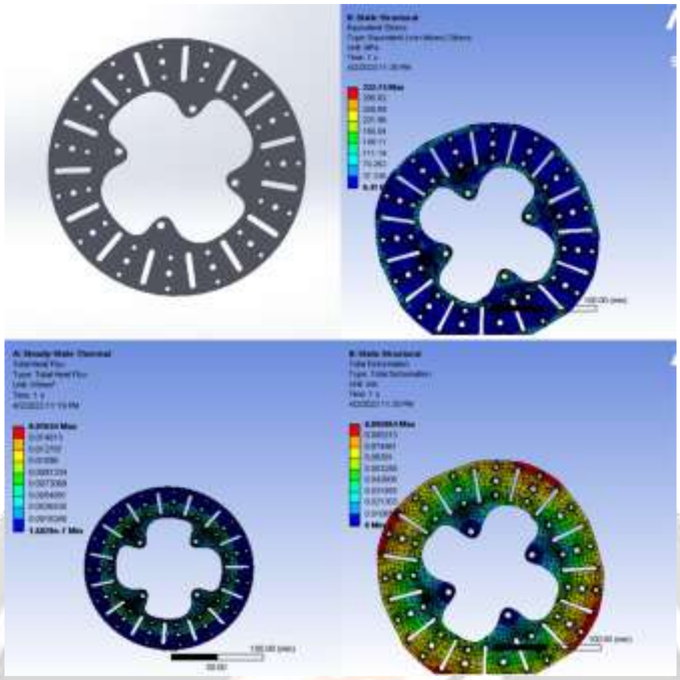


Fig -3: Cast Iron

	SS-304	EN-19	Cast Iron
Total heat flux (W/mm^2)	0.012814	0.01799	0.01644
Equivalent (von misses) Stress (MPa)	466.28	988.99	332.74
Total deformation (mm)	0.075894	0.16077	0.95864

Table-5: Results

5. CONCLUSIONS

Stainless steel 304 drilled and slotted disc rotors could be a useful option for Formula SAE vehicles due to their benefits such as improved heat dissipation, water and debris dispersion, and overall braking performance. It's important to take into account any potential drawbacks, including higher expenses and speedier wear as well as the possibility of stress risers and cracking under extreme conditions. Last but not least, the design and material of the brake rotor should be chosen depending on the demands and specifications of the vehicle, taking into account factors like budget, intended use, and safety concerns.

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