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Design and Thermal Analysis of Brake Disc for Optimum Performance

Aakash Jawla[1], Rahul Anand[2], Shobhit Agarwal[3], Aman Gupta[4], Jiwan Jyoti Jena[5]
[1, 2, 3, 4, 5]*School of Mechanical Engineering, Galgotias University. Greater Noida, India*

Abstract: While designing a formula car the first thing that came into mind is safety as we know a formula car experience immense mechanical & kinetic loads mostly during braking. This paper addresses at designing and thermal analysing Disk (Brakes Disk) of Formula SAE car for Automantra Racing, SAE team of Galgotias University. When the brakes are applied to the moving vehicle, all the kinetic energy of the vehicle get converted into equivalent amount of heat generation. But during the hard braking there is induction of thermal stress which generates excessive amount of heat & we all know that a small portion of disk is in contact with friction pads of callipers. The Aim of this project is to study the Thermal analysis of the materials for Stainless steel. Disc brake design is done through SolidWorks and analysis is completed by using ANSYS workbench
Keywords: SolidWorks, FSAE, Ansys, Thermal Analysis

I. INTRODUCTION

AUTOMANTRA RACING is the formula student team of students studying in Galgotias University, Gautam Buddha Nagar, U.P., INDIA. The team works together to participate in an engineering design competition with the collective aim of building an open wheeled formula style student concept car which is completely fabricated by the students to participate in the Formula Bharat event by Formula SAE International.

Here, at Automantra Racing, the students collectively aim to design and analyse the brake disc on its thermal results and put out the best possible results for a certain material that has been taken to achieve maximum efficiency and the paper will serve as a base for the students that are willing to work on the same in near future.

Brakes are broadly classified into two types: -

1) *Axial Brakes:* In these types of brakes, the force acting on the braking system is in the axial direction to the brakes. For example: - In disc brake the piston is acting on the axial direction on the disc by brake pads.
2) *Radial Brakes:* In these types of brakes, the force acting on the braking system is in perpendicular direction to axial direction. Radial brake is sub-divided into internal and external brakes.

The type of braking system that we are experimenting here is of axial type. Brake disc is one of the most important components of any vehicle that comprises it. There is another way of braking that includes drum brakes but in comparison to disc brakes they are less efficient and disc brakes are even less bulky with an added feature of less weight. The disc brakes supply driver with an extra bit of confidence while braking as the output tends to be faster and accountable. The feedback that the driver gets from a disc brake is comparatively easy to judge and the decision taking time reduces and the action on the racetrack increases.

II. LITERATURE REVIEW

A. "Disc Brake Rotor Selection through Finite Element Analysis" by Swapnil Umale, Dheeraj Varma this research paper gives us information about working principle characteristics, applications & various loads acting of disc brakes along with broad descriptions.
B. "Thermal Analysis of Disc brake Using ANSYS" by Avinash Singh Thakur, Asst. Prof. P.S. Dhakad helps us is selection material for our disk. As the maximum temperature rise of cast iron disc is much small with compared to stainless steel, cast iron is the best desirable for manufacturing disc brake. But cast-iron disc brake gets corroded when it comes in contact with wetness and hence it cannot be used, thus we prefer stainless steel.
C. "Experimental and Numerical Thermal Analysis of Formula Student Racing Car Disc Brake Design" Manthan Vidiya and Balbir Singh this paper belongs to 'Formula Manipal', the official Formula student team of Manipal University, India. This paper provides us formulas for calculating Heat Generated, Friction Force, Heat flux, Heat Absorbed & Change in Temperature.
D. "Thermal Analysis Of Brake Disc" by Swapnil.D.Kulkarni , J.J.Salunke this paper is from Mechanical Engineering Department, DIEMS, Maharashtra, India Introduce us with procedure followed during the analysis by performing an analysis on disc with 3 different materials.

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III.THEORY

Brake is the part in a vehicle that resist the motion of the vehicle's wheel on the will of the driver. One of the most used types of brake is the desk brake. It is a kind of mechanical brake and works on the principle Pascal's Law of pressure.

In disk brakes pads are pushed against the disk which rotates with the wheel. The friction between the pads and disk resists the rotation of the brake disk and simultaneously the rotation of the wheel.

Due to the friction between pads and disk, the disk gets hotter due to conversion of the kinetic energy of the wheel into thermal energy of the brake disk. The heat generated in the disk dissipated into the air and the disc gets cooler again. The dissipation is necessary for braking because if the heat doesn't dissipate, the disk will get excessively hot and eventually the breaking mechanism will fail. Due to this reason the disk should be designed will well so that the heat transfer from the disk to the air should be optimum.

IV.METHODOLOGY

We have started with finalising the type of brake callipers that we want to use for the car and eventually after team discussion it was decided that KBX is the one we are selection. Reasons for selecting KBX is really simple, these callipers are having two pistons one for each brake pad and despite having two piston these are small in size and because of small size they are very light in weight which helps to keep the overall weight of car in watch. The mounting points of these callipers also matches with the designed mounting points of hubs accurately. After selecting the type of calliper process becomes easy as now, we have to decide the diameter of our disc and in this case it is. Various holes are drilled in the disc the reason behind this is that these holes do not make any impact/changes on the stress and strain of the disc also it helps to reduce the weight of the disc to a drastic to a drastic level. Holes in the disc are also helpful because they help in the process of heat dissipation as when the disc of breaks heat it makes an impact on the braking efficiency so it is also important that disc should remain cool in this process.

The above fact of heat dissipation leads us to the goal of this research and helps us understand about heating of the disc.

The Analysis in ANSYS is carried by following method.

A. First of all, the profiles are created in Creo parametric 2.0.
B. After starting ANSYS 15.0, the mode of analysis is taken as steady state thermal.
C. The material properties are defined for the profile models.
D. The model is then subjected to meshing as Fine.
E. After meshing, the boundary conditions are applied to the brake disc.
F. The parameters whose solution is required are selected from the solution bar.

V. CALCULATIONS

The calculations are done by considering the weight of vehicle 300kg & top speed of 100kmph.

1) Mass of the vehicle: 300kg.
2) Maximum speed of vehicle: 100kmph.
3) Kinetic energy of the vehicle :$0.5mv^2$
4) Rotor disc diameter in meter:0.200m
5) Permissible temperature in Celsius: 2500 C.
6) Pressure applied on the brake pads: 1Mpa.
7) Tangential force acting on the disc:2835.20 N.
8) Generated heat flux for above condition for stainless steel: 23148.14 watt/m^2.

A. Formulas Used

$Power = Force \times \Delta$

Friction Force $f_f = \mu_d \times A_p \times pr \times n$

Heat Partition Coefficient: $p = \frac{\sqrt{k_d \times \rho_d \times c_d} \times S_d}{\sqrt{k_d \times \rho_d \times c_d} \times S_d + \sqrt{k_p \times \rho_p \times c_p} \times S_p}$

Heat Absorbed: $H_d = p \times H$

Convection: $H_{convectin} = h \times A \times \Delta T$

Radiation: $H_{rad} = \sigma \times A \times \Delta T^4$

Temperature Rise: $\nabla T_d = \frac{H_d - H_{convection} - H_{Rad}}{m_d \times c_d}$

VI. MATERIAL SELECTION

Selection of material for manufacturing is also a very complex and important aspect. While selecting materials various factors can be taken into consideration such as thermal conductivity, coefficient of friction & corrosivity etc.

TABLE 1

Property	Stainless Steel
Density	7800
Youngs Modulus	200
Poisons Ratio	0.3
Thermal Conductivity	28
Specific Heat	500
Coefficient of Friction	0.23

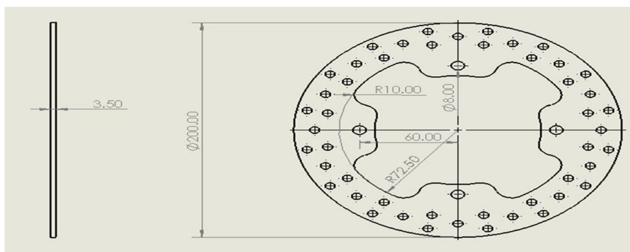

Figure 1: CAD Drawing of AR20 Disk

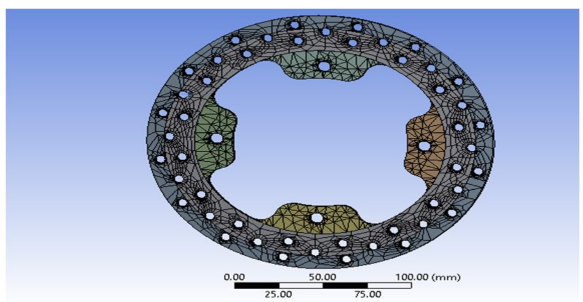

Figure 2: Meshing Details

VII. RESULT

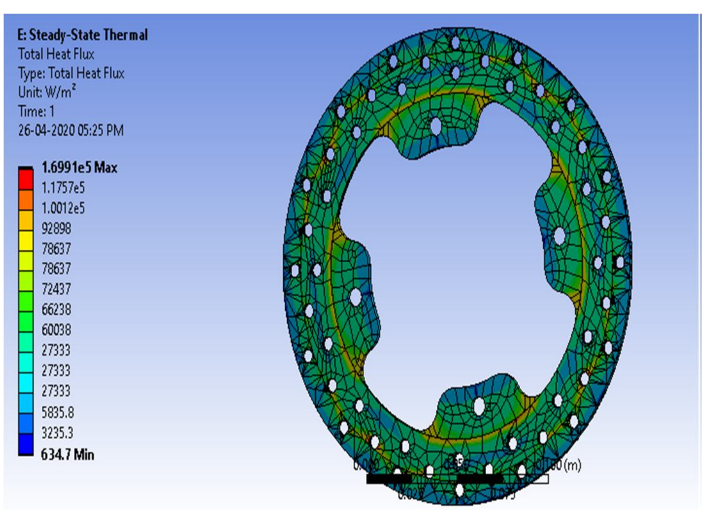

Figure 3: Heat Flux on Disc

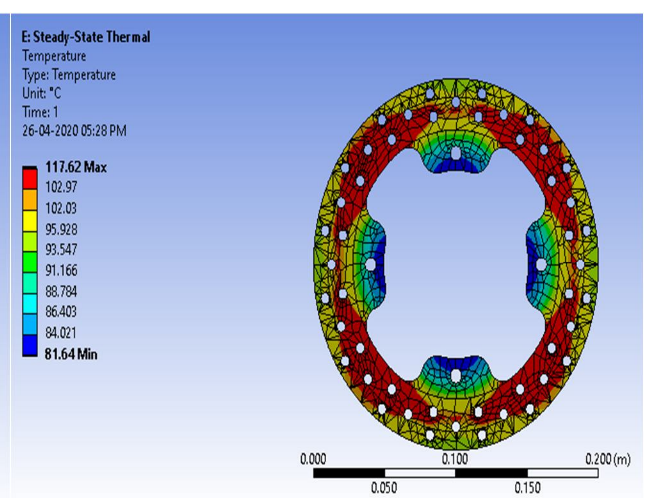

Figure 4: Temperature

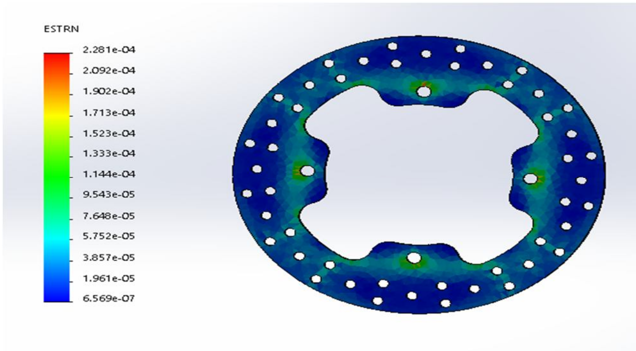

Figure 5: Equivalent Strain

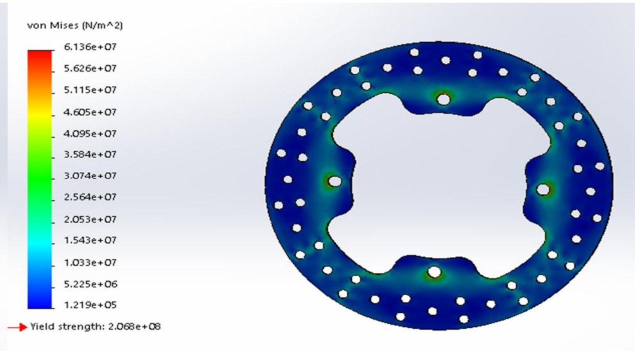

Figure 6: Equivalent Stress

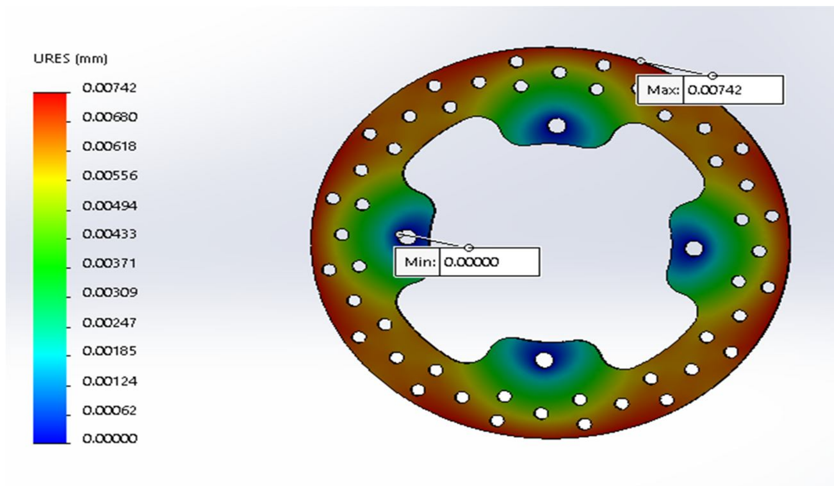

Figure 7: Total Displacement

TABLE 2

S.NO	PARAMETER	MAXIMUM VALUE	MINIMUM VALUE
1.	EQUIVALENT STRAIN	2.281E-04	6.5696E-07
2.	EQUIVALENT STRESS	6.136E+07	1.216E+05
3.	TOTAL DEFORMATION	0.007	00
4.	HEAT FLUX	1.6991E+05	634
5.	TEMPERATURE	117.68	81.64

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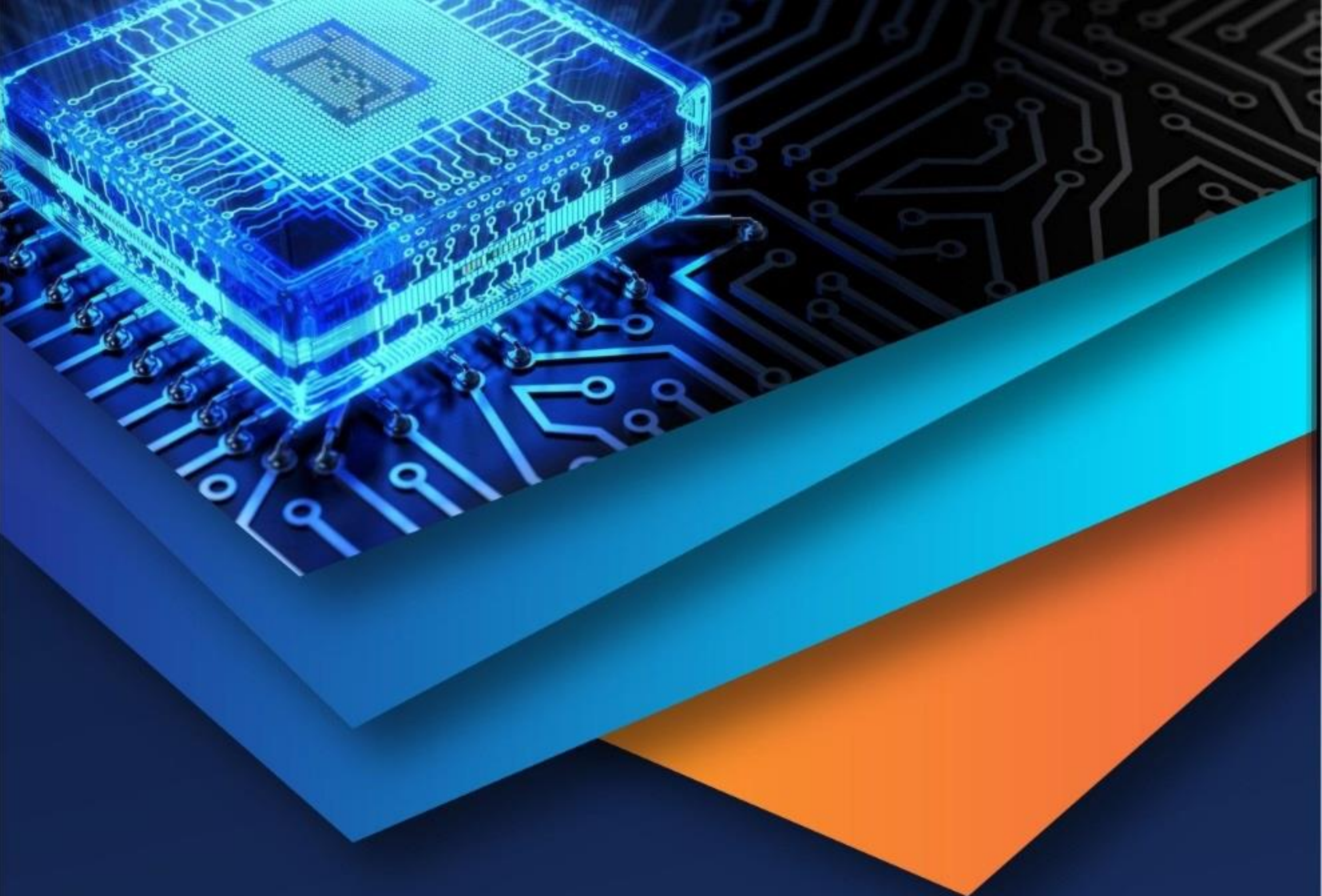

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