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Desigh, Development And Analysis Of Braking System For Student Formula Race Car.

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ABSTRACT:
FORMULA BHARAT & SUPRA SAEINDIA are an annual national level competition organized in the India. From all over India, the selected Under Graduate & Post Graduate Engineering Student teams must design, model, fabricate and compete with a small open-wheel, open cockpit type race car.

The basic aim of this work is to achieve the required standards for brake design and to scale through the dynamic test at the competition. This work serves as a study for developing a desired braking system for high-performance race cars. Fundamentals of vehicle statics, dynamics and previous research works are considered for designing and analyzing components of braking system. For design and analysis use of Dassault solid works 2017-18 and Ansys 2019R-2 is done. The considerations for designing brake system are material, ergonomics, maximum braking force, safe stopping distance lightweight, manageable temperature and reliability. The proper ratio of brake force of front to rear axle is calculated for locking all the four wheels reducing stopping distance and comply with rules. Structural and thermal stresses developed are obtained from static structural and steady state thermal analysis. The boundary conditions used for the analysis are braking torque, heat flux and convection coefficient.

I. INTRODUCTION:

The braking system for the 2020-21 FSAE car was designed to be lightweight and compact while still providing adequate stopping power. The braking system had to provide enough braking force to completely lock the wheels at the end of a specified acceleration run, but remain small enough to fit inside of the front wheels and also prove to be cost effective. The braking system was designed by first determining parameters necessary to produce a given deceleration, and comparing to the deceleration that a known braking system would produce.

Certain assumptions about the car had to be made before the necessary calculations could be performed. It was assumed that the car would weigh 600 pounds with driver, and the location of the car's CG was approximated based on the positions of the engine and driver. Following this, a basic model of the car was drawn, including the weight of the car, the locations of the centre of gravity and axles, and also the distances between these points and ground. A worst case deceleration of 1.5 g was assumed, since the car would not likely be decelerating at a rate faster than this. Using this information, the amount of the car's weight on both the front and rear set of tires under deceleration could be determined. This number was then used as the normal force experienced by the tires to determine the necessary friction force required to produce the given deceleration. With the friction force applied by the front and rear tires determined, the next step was to determine the required brake torque. Brake torque is simply the amount of torque that the braking system needs to develop in order to produce the given deceleration.

SELECTION OF COMPONENTS:

A. Calipers:

A brake caliper forms a significant part of a car's disc brake system.

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Thereisusuallyoneperwheel(supercarscanhavetwoperwheel)andithouses caliper mounting bolts, bushings, pistons, seals, dust boots, retainers, noise shims,thebrakepadsandanti-rattleclips.By comparing torque required for braking and the torque developedby caliper, we preferred the Vespa calipers for ourvehicle.

A. Master Cylinder:

A tandem type master cylinder was selected so that independent two hydraulic circuits can be obtained and it can be obtained control by single control from brake pedal. It contained DOT4 oil. A diagonally spilt-connections were given to the wheels so that car maintains stability in case of failure of one of the circuits. The circuit is made up of the rigid pipes followed by flexible brake lines going to the caliper through a Benjo bolts.

B. Brake pedal:

The pedal design is important, especially at the contact point from the foot of the driver, because that is where the most force would be applied. In general, thebrakepedalneededtotakea 2000Nforce, butneededtoalsobelightweight fordesignpoints.Also,theheightofthepedalpadshould beabouttheaverage height of the length of a male's foot from heel to sole, about 270 to 290 mm , but be able to accommodate smaller and larger sized feet. Due to the forward position of the hydraulic cylinders, the connection between the brake and the cylinders was set, except for the adjustability of the pedal ratio. The easiest way to make the ratio adjustable was to add drilled holes within the pedal and have the connection from the pedaltothehydrauliccylinderstobeabletovary. However, another option was to make an adjustable balance bar on the cylinders to change the angle of the initial pedalposition.
The ratio and geometry was designed for the comfort of the drivers. The pedal ratio could be calculated using equation ratio of x:y. The adjustability of the pedalneededtobeintherangeofa6:1to4:1pedalratioin orderfortheapplied forcecalculationstobewithinareasonablerangeforthe drivertolockallfour wheels with the brake pressure.

BRAKING SYSTEMSPECIFICATIONS

Table -1: Braking System Parameters

Sr.No.	Parameters	Value
1	Driver Force	400 N
2	Leaverage Ratio	6:1
3	Master Cylinder Diameter	19.05mm
4	Area Of Master Cylinder	285.022 mm^2
5	Caliper Piston Diameter	30 mm
6	Area Of Caliper Piston	706.85 mm^2
7	Tire Diameter	10 Inch
8	Disc Thickness	4mm
9	Wheel Base	1600mm
10	Mass Of Vehicle	230kg
11	Weight Of Vehicle	2256.3n
12	Height Of Cg	310mm
13	Cg From Front Axle	880mm
14	Decelearation	1.5g
15	Velocity	16.66m/s

- Front calliper: Vespa double piston callipers having bore dia.30mm
- Rear callipers: Vespa double piston callipers having bore dia.30mm
- Master cylinder : Maruti 800 tandem master cylinder having bore diameter 19.5mm
- Pedal ratio :6:1

BRAKECALCULATIONS

- Deceleration a = 1.5×9.81 =14.71m/s^2
- C.G. height= ycg =310mm=0.31m
- Distance of C.G. from front axle = Xcg = 880mm =0.88m

- Wheel base = b =1600mm=1.6m

- Rolling radius = r = 205 mm= 0.205m Mass of car = 230kg

- Normal Forces On Front And Rear Tyres- Nrear =585.45 N

Nfront =1670.85 N

% Of Normal Force On Front Tyre=74.05%

- Braking Torque Required, μ =1.5

- Frictional Forces On Front Tires Ff = 2506.275N

- Frictional Forces On Rear Tires Fr = 878.175N

- Braking Torque On FrontTires

- Trf = 513.786 N-M(Required)

- Braking Torque On RearTires

- Trr = 180.025 N-M (Required) Pressure = 8.42 N/mm^2

Stopping distance:

Stopping distance is the distance measured between break applied by the driver and the vehicle gets complete stop. The distance travelled by the vehicle when brake is applied. The stopping distance depends upon several factors including deceleration rate, percentage of grade for operation, vehicle speed, road surface characteristics.

Stoping distance, d = 8 m.
Brake Torque Developed-
Td = 1104.096 N-M (Developed)

By comparing torque required for braking and the torque developed by caliper, we preferred the Vespa calipers for our vehicle.

BRAKEDISC

The brake disc is used to stop the car/motorcycle with the help of calliper pads. The calliper pads are actuated by a fluid present in the hydraulic circuit. The wheel assembly of the car consists of knuckle (upright), stub, hubs, bearings and disc. The brake discs are mounted on the hub which is connected to the wheels directly. The disc is mounted behind the hub. The knuckle have a special arrangement for mounting a calliper on it. The part of the disc is inserted in the space present between the calliper pads. The part of the disc which is in contact with the calliper pads is known as pad area on thedisc.

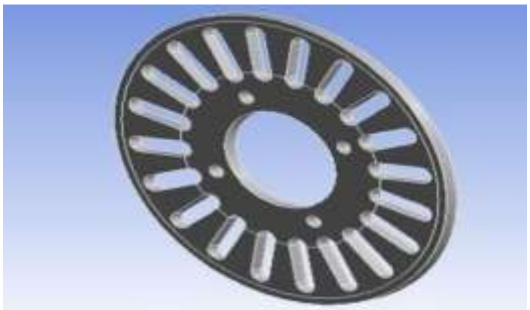

Fig -1: Brake Disc

For analysing the discs some assumptions are to be done as well as calculations of some parameters are required. Considering mass of the car is 230 kg. Now considering the car is travelling at a speed of 65 km/hr on a race track (formula race track) and it suddenly applies a brake which decelerates the car and at the end car stops. During the steady state thermal analysis the disc get analysed for maximum temperature distribution on the pad area of the disc in order to understood proper heat dissipation takes place through the discsurface.

Initial temperature (ambient temperature) = 22° C

- Velocity = 65 km/h =17.67m/s
- Mass (M) = 230kg
- Weight = 2256N
- Coefficient of friction between road and tyre (μ) =0.8

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- Brake disc diameter = D = 0.155m
- Axleweightdistribution()=0.4
- Percentage of kinetic energy that disc can absorb =(f)=0.9
- Acceleration due to gravity (g) =9.81m/s^2
- Coefficient of friction between disc and pads = (μ) =0.3
- Kinetic energy of the system can be givenas,

K.E. = 6463.8 J Deceleration Time (t), v= u + at t= 2.85 sec

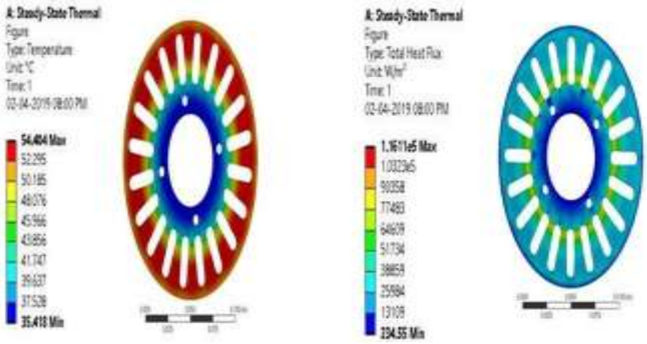
- Braking power (pb) = K.E. / t pb = 2268W
- Heat flux = (Q)=Pb/A

= 120195 W/m^2

But the distribution of braking torque vehicle is about 64:40 and the heat flux for single disc can be evaluated by dividing total heat flux by two. And by considering the weight distribution factor, the heat flux Q is equals to 23040 W/m^2.

Analysis of BrakeDisc

We used ANSYS for the analysis and validation of the design.



(a) (b)

Fig -2: (a)Steady state thermal analysis of Temperature distribution through disc, (b). Steady state thermal analysis of total heat flux through disc.

BrakePedal

The pedal design is important, especially at the contact point from the foot of the driver, because that is where the most force would be applied. In general, the brake pedal needed to take a 2000 N force, but needed to also be lightweight for design points. Also, the height of the pedal pad should be about the average height of the length of a male's foot from heel to sole, about 270 to 290 mm , but be able to accommodate smaller and larger sized feet. The Brake Pedal is manufactured in aluminium by considering factor of safety 1.2.

The brake pedal is designed according to design procedure of bell crank lever. The master cylinder pivot is about 35mm above the brake pedal pivot. For designing the brake pedal the pedal ratio is considered as 6:1 and the driver force considered as 400 N.

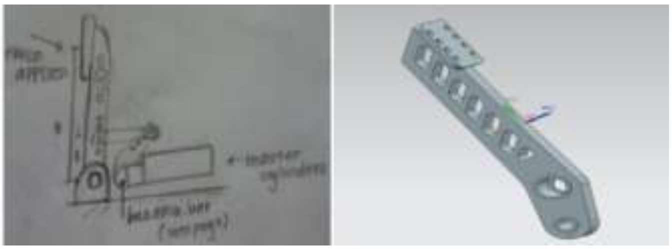


Fig -3: Brake Pedal Initial and Final Design Sketch.

Analysis of BrakePedal

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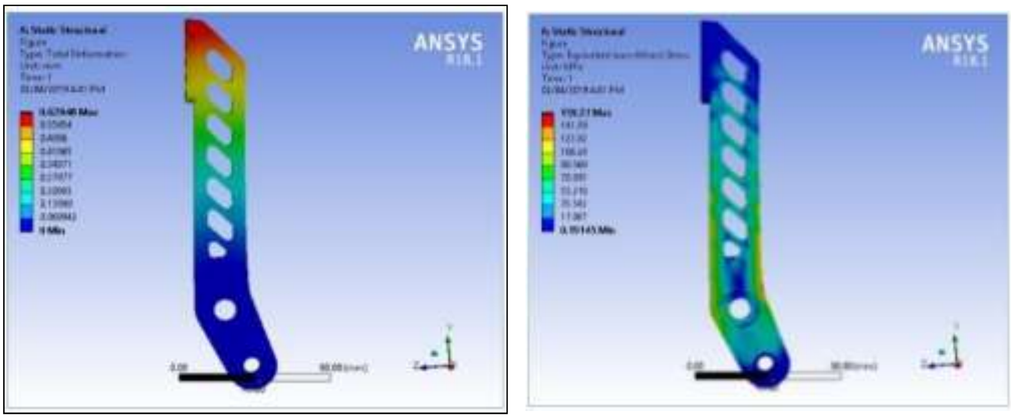

(a) (b)

Fig. 4:(a) Static Structural Analysis of Total Deformation Of Brake Pedal, (b) Static Structural Analysis Of Equivalent (Von-Mises) Stress.

To eliminate small objects, connected component labelling is applied to the resultant image.(c) represents text detection by applying second set of criteria which eliminates all the objects whose area is less than 300 and filled area is less than 500.

Fig -5: Brake disc & caliper assembly

II. CONCLUSIONS

It was necessary to design a braking system which is light in weight and compact while still provides adequate stopping power and to cover these aspects we selected hydraulic braking system. While doing this project we understood how an effective braking system should be designed, manufactured and optimized. This Project has cleared our basic knowledge about mechanical system design. This idea has given us hands on experience on designing a hydraulic braking system which is very useful for future.

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