Design and Analysis of FSAE Brake Disc

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***Abstract*— In the modern age, the demand for the automobile has been increasing for the last few decades and the requirement of each is different. The need of the customer is to have and drive comfortable and safe vehicles to enjoy the journeys. The most important safety feature of any vehicle is the braking system. The modern age engineers are fulfilling the aspects to provide high-performing brake systems. The fundamental requirement of any brake system is to deaccelerate a vehicle precisely in variable conditions. The main function of the brake is to dissipate the converted kinetic energy in the form of heat. It is also composed of a set of mechanical parts such as springs, calipers, master cylinders, brake pads, brake disk, and different types of materials (Metallic and Non-Metallic), gases, and liquids. This complete assembly is mounted on the wheel hub. The Driver applies force on the pedal which them transmitted by a series of force manipulations to the calipers. As the brake disc will go through lots of forces and several critical conditions so it should be sustained variable conditions, as perhaps the brake rotors and most abused part in vehicle after tires. Brake discs usually are made up of ceramics, stainless steel (variable composition). Therefore, careful consideration of material for brake discs and their design plays a key role in the design of a braking system of the vehicle. The paper is concerned with the designing of the brake disc, selection of material, analysis of the disc on ANSYS software.**

Keywords*— *Brake disc, static analysis, thermal analysis, FEA

I. INTRODUCTION

The stopping mechanism is, without a doubt most significant segment of the vehicles as the wellbeing of the traveler is thoroughly relied upon it, as they are utilized to end the vehicle or to ease back the vehicle to a necessary speed from a given introductory speed. Because of globalization and the modernization of the world, the interest in all kinds of vehicles is at its peak. All Vehicles required productive stopping mechanisms. For the most part, 70 % of the active energy of the vehicle is consumed by the front brakes and the rest of consumed by the back brakes. Brakes should perform securely under all sensibly predictable working conditions, including tricky, wet, and dry streets; while slowing down straight or while turning; with new or worn brakes; on smooth or harsh streets; or when pulling a trailer. The slowing mechanism should work under predictable conditions, at the sensible expense and brake wear life while giving directional solidness and worthy tire-street rubbing usage.

Brakes are comprehensively Named as follows: first and foremost, as per wellspring of the utilization of power as – mechanical brakes, pressure-driven brakes, and pneumatic brakes and besides as indicated by calculation as drum-type brakes and plate type brakes. A portion of the benefits of pressure-driven brakes is that they have speedy reaction, more noteworthy power age limit, minimized size, diminished weight, non-reliance on the power unit, and more prominent criticism. The force of supplanting mechanical brakes, which are considerably more reduced, emerged from the way that as vehicles turned out to be quicker and quicker, the power required creating required slowing down exertion, expanded essentially. Along these lines, the auto industry built up a more exquisite answer for the above issue in type of water-driven brakes.

Right now, ventilated circle brakes are utilized because they have high warmth dissemination attributes. The ongoing examination has shown that ventilated plates have high warmth move rates because of an expansion in choppiness which brings about a higher warmth move coefficient of temperature. Ventilated circles likewise have more prominent protection from warm distortion because of the uniform circulation of the material, which lessens the warm pressure amassed inside the rotor, which relies principally upon the calculation of the plate and the ideal setup of the ventilation channels

As per the guidelines of the opposition, the vehicle should be furnished with a slowing mechanism that follows up on each of the four haggles worked by a solitary control and it should have two autonomous water-driven circuits to such an extent that on account of a break or disappointment anytime in the framework, successful slowing down power is kept upon in any event two wheels. Each pressure-driven circuit should have its liquid hold, either by the utilization of discrete supplies or by the utilization of a dammed, OEM-style repository.

The progression of the stopping mechanism is as per the following: the driver applies power on the brake pedal, the brake pedal channels that power to the expert chambers, subsequently dislodging the slowing down liquid in the expert chambers. The uprooted liquid at that point applies tension on every one of the calipers permitting the caliper cylinders to apply a clipping power on the rotors. Hence, the contribution of the framework is the driver's applied foot power and the yield is the cinching power of the calipers applied on the rotors.

II. DESIGN OF BRAKE DISC

The brake disc is designed in Creo 5.0. The material for the brake disc is stainless steel 304.

TABLE I. Parameters

Parameters	dimensions
The outer diameter of the rotor, mm	183
The inner diameter of the rotor, mm	133
Disc thickness, mm	5*
Clap hole Diameter, mm	*
Number of clap hole	6
Piston area, mm^2	0.79ft

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TABLE II. Material properties

Tensile strength ultimate	505MPA
Tensile strength yield	215 MPa
Poison's Ratio	0.265
Modulus of rigidity	193 - 200 GPa
Heat flux	0.19w/mm2
Convection coefficient	230 wm-2 C

TABLE III. Composition of material

Fe	64.99-74%
Ni	18%
Cr	8%
Mn	2%
N	0.10%
C	0.03%
S	0.08%
Si	0.75%
p	0.045%

III. MANUFACTURING PROCESS

The assembling strategy utilized in the development of brake circles is the metal casting process and to be more explicit, it is the extremely durable shape projecting cycle that happens in the creation of these brake plates that generally gives out a decent surface completion for the final result.

To start this interaction following fixings, short carbon filaments, carbon powder, and heat-molded should be blended. Then, at that point, utilizing an automated machine this blend is filled with an extremely durable aluminium form pit which is looking like a brake plate (circle ring) until it is half full. When it is half full, the form is eliminated and laborers need to embed aluminium centers into a belt with holes around the shape that permits the centers to be embedded into the shape. These centers will shape a ventilation depression in the plate ring (brake circle) to keep the circle from overheating.

The form again moves once more into the mechanized machine to fill the other portion of the shape pit with the remainder of the combination that was filled the primary portion of the depression. When the depression is full it is evened out utilizing a roller and afterward utilizing the cover or the other portion of the extremely durable shape, it is covered and is squeezed softly to reduce the substance inside. Then, at that point, the completely covered form is shipped off an enormous press which applies 20 tons of tension and warming to practically 400oF. This hotness and tension smaller the carbon fiber and sap into plastic and make it more grounded.

When the form is chilled off to be dealt with, lower it in chilly water for 5-8 minutes which cools the plate ring totally, empowering them to take out the centers that were embedded for ventilation purposes. When every one of the centers has been eliminated, eliminate the front of the shape and take out the plate ring from the form Then, at that point, utilizing the computer-guided machines smooth out every one of the unpleasant edges on the circle ring and drill minuscule ventilation openings. They then, at that point, put the plate ring into a broiler and for more than two days it steadily warms it to 1800oF. This would then reason the substance change which changes plastic into carbon. Then, at that point, take a cauldron which is a high hotness safe compartment, and spot five mounts inside so it can hold the circle ring on them without having the plate ring contact the foundation of the pot. When the plate is mounted on the pot, place a channel at the focal point of the circle ring and fill it with a fine silicon powder. Then, at that point, they load the pot into a heater for 24hours, and all permits to steadily warm the circle ring to the temperature of 3000ºF until the silicon is dissolved totally. This fluid silicon is then brought into the circle ring by the pores of the structure of the plate ring and structures a new material called silicon carbide which makes the plate ring outstandingly hard.

Whenever it is eliminated from the heater, a drill machine drills the mounting openings on the plate ring. And afterward, the plate ring goes to a chamber to get a layer of defensive paint. This paint is utilized to safeguard the carbon and circle ring from oxygen and this cycle is extremely basic since, at high temperatures, oxygen consumes carbon. Subsequently, this enemy of the oxidation process expands the lifetime of the plate ring. When the defensive player is applied, with the assistance of a computer-guided robot arm, moves the plate and cleans the whole circle surface after when all the cleaning has been finished, the computer-guided machine completely reviews the plate ring surface by taking top-quality photos to additionally look at the atomic and gem constructions to identify any imperfections.

CALCULATIONS

1. Dynamic Weight Transfer:
   a. $W_t = \frac{h*m*d}{g*b} = \frac{300*280*1.5}{1530}$ ………d/g=1.5
   $= 82.35$ Kg

2. Static Weight Distribution = 45:65
   a. Front Weight = 126 Kg
   b. Rear Weight = 154 Kg
   c. Front Weight transfer =126 + 82.35
   = 208.35 Kg
   d. Rear Weight transfer = 154 – 82.35 = 71.65 Kg
   e. Weight Transfer Ratio = $\frac{208.35}{71.65}$ = 0.74:0.26

3. Total Energy:
   a. Translational = $\frac{1}{2}*m*v^2$
   $= \frac{1}{2}*280*(60*5/18)^2 = 38.88$ KJ
   b. Rotational $= \frac{1}{2}*I*W^2$

   $= \frac{1}{2}*m_t*K^2*(v/r)^2$
   $= \frac{1}{2}*48*(0.4*165.1)^2*(\frac{60*5/18}{0.252})^2$

   = 455.67 J
   c. Total Energy = Translational + Rotation
   = 38.88+0.45567
   = 39.33567 KJ

4. Torque Due to Friction = $T_f = \mu*w*R$
   = 1.5*280*9.81*0.2526
   = 1038.39 Nm

5. Braking Torque:
   a. $R_{(eff)} = (\frac{Do + Di}{4}) = (\frac{183+133}{4}) = 79\ mm$

b. Braking Torque = Braking Force* $R_{(eff)}$
= 340.745 Nm

6. Torque on front Wheel = Dynamic Weight transfer @ front Wheel*B.T.
= 0.74*340.745
= 258.07 Nm
   a. Torque on Each front Wheel = 258.07/2
   = 129.035 Nm
   b. Clamping Force
   $\left(\frac{Torque\ on\ each\ front\ wheel\ /\ R(eff)}{\mu p}\right) = \left(\frac{129.03/0.079}{0.4}\right)$
   = 4083.41 N
   c. Clamping Force on each piston = 4083.41/2
   = 2041.70 N

7. Pressure in Front Circuits
   a. Force Exerted = 33*9.81= 327.73 N
   b. Pedal Ratio = 5
   c. Total force on pedal = 1618.65 N
   d. For Balancing, 65:35
   e. So, force on front master cylinder = 1052.12 N
   f. Pressure in Front circuit = $\frac{Pedal\ force}{Area\ of\ Master\ cylinder}$
   $= \left(\frac{1052.12}{\frac{\pi}{4}*(19.05)*(19.05)}\right)$
   = 36.93 Bar

8. Pressure in Rear Circuits
   a. Torque on real wheel = 0.26*340.745
   = 88.59 Nm
   b. Torque on each real wheel = 44.295 Nm
   c. Clamping Force = $\frac{44.295/0.079}{0.4}$
   = 1401.74 N
   d. Clamping Force on each rear wheel = 700.87 N
   e. Force on rear cylinder = 1618.65*0.35
   = 566.52 N
   f. Pressure in rear circuit = $\frac{566.52}{\frac{\pi}{4}*19.05*19.05}$
   = 19.87 Bar

IV. BOUNDARY CONDITIONS

The translational and rotational motions of the discs are constrained by fixing in clamping holes. The force of 2041.7N is applied to the contact area of the brake pad and disc from both sides on the x-axis.

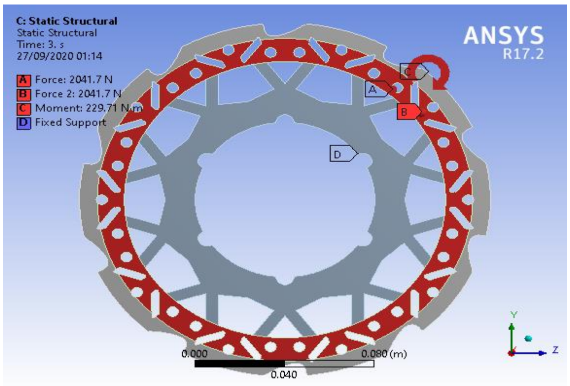

Fig. 1 Static structure

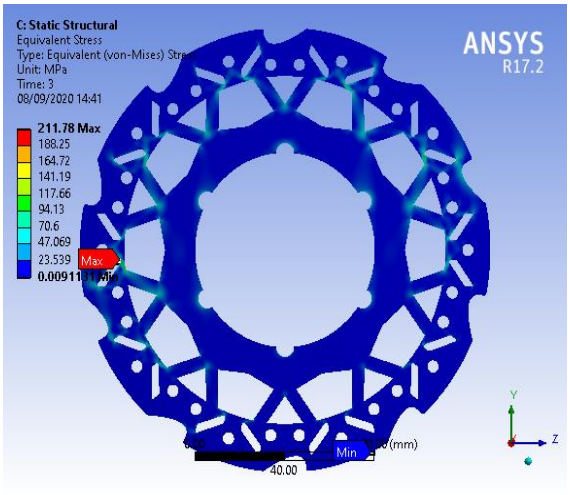

Fig. 2 Equivalent Von-mises stress

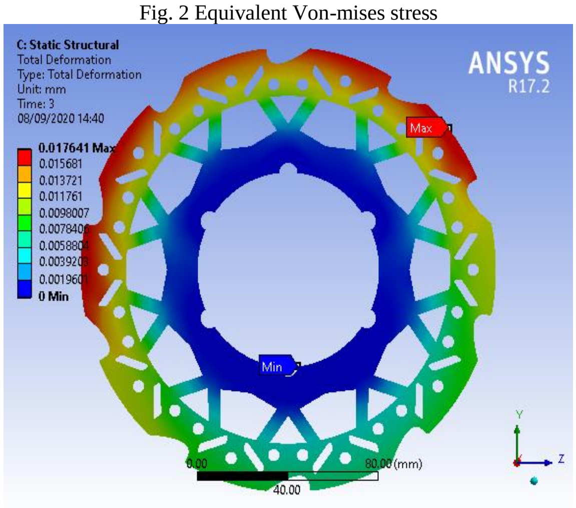

Fig. 3 Total Deformation

V. ANALYSIS

1. Thermal Analysis

Transient Thermal examination is utilized to decide temperature and other thermal quantities that change over the long haul. The adjustment of temperature dispersion over the long run is significant in numerous applications, for example, in quenching analysis for heat treatment. Likewise of interest are the temperature circulation brings about thermal stress that can cause the failure. In such cases temperature from the transient thermal analysis for thermal stress assessment. Heat flux is applied for various design structure plates is 0.19W/mm2. The accompanying figure shows the aftereffect of transient investigation in different circles.

As displayed in the above figure transient warm examination was led on the plate and the greatest temperature noticed is 85.26 and the base temperature noticed is 24.36.

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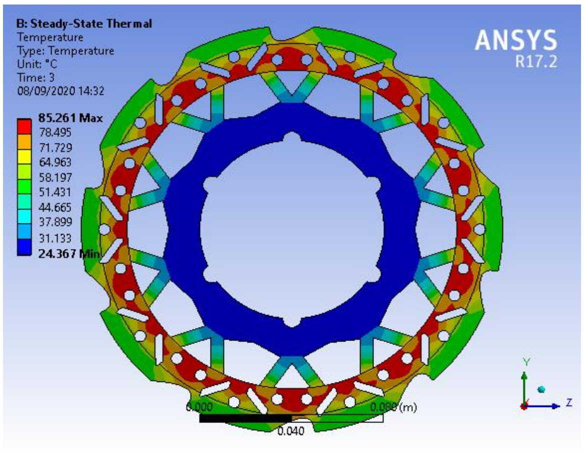

Fig. 4 Static state Thermal Analysis

Result

Flux	0.19w/mm2
Max temp	85.26

2. Static Analysis

The purpose of the static structural analysis is to find maximum stress induced in the brake disc during maximum braking conditions. When the maximum braking force is applied by the brake pad on the disc, the kinetic energy of the disc is converted into heat energy, and the compression force is experienced by the disc. Due to compression force, compressive stress gets induced in the disc. If this compressive stress (von misses) is greater than yield (permissible) compressive stress of material it causes failure.

To calculate maximum stress induced by FEA braking force is applied on an element of the area in contact with the brake pad (f = 2041.7 N) and the disc gets fixed at its mounting points. For safe conditions of disc comp stress, induced should be less than permissible stress value.

Result

Maximum deformation	0.017641 mm
Von misses stress	211.78
Factory of safety	215/211.78=1.01

REFERENCES

[1] Swapnil R. Abhang, D.P Bhaskar, International journal of engineering trends and technology (IJETT), “Design analysis of disc brake”, Volume 8 Number 4-Feb 2014
[2] R. Lakshmanaik, Dr. T. Dharma Raju, “Analysis of disc brake by using FEA and ansys”, International journal of advances in applied Science and engineering (IJAEAS), ISSN (p): 2348-1811, vol-1, iss. -3, pages 136-142, June 2014
[3] Rakesh Jaiswal, Anupam Raj Jha, Anush Karki, Debayan Das, Pawan Jaiswal, Saurav Rajgadia, and Ankit Basnet, International Journal of Mechanical Engineering and Technology (IJMET), “Structural and thermal analysis of disc brake using Solidworks and ANSYS”, Volume 7, Issue 1 Jan- Feb 2016, pp. 67-77, Article ID: IJMET_07_01_008.
[4] Abhishek Kumar Tiwari, Akhilesh Kumar Tiwari, “Finite Element Analysis of Disc Brake for Aluminium Alloys”, International Journal of Scientific & Engineering Research, Volume 5, Issue 4, April-2014. R. Nicole, “Title of paper with only first word capitalized,” J. Name Stand. Abbrev., in press.
[5] Viraj Parab, Kunal Naik- "Structural and Thermal Analysis of Disc Brake", IJEDR Volume2, Issue2, ISSN:2321-9939.
[6] A. Belhocine, M. Bouchetara- “Thermal behaviour of full and ventilated Disc Brakes of vehicles”, Volume 26, Issue 11, November 2012, pp 3643-3652.
[7] C. Radhakrishnan, K. Yokeshwaran, M. VenkadeshPrasadh, A. Vishnuhasan, T. Vimalraj, M. Velusamy- "Design and Analysis of Disc Brake with Titanium Alloy", IJISET, Volume 2, Issue 5, May 2015.
[8] Bouchetara, M., and Belhocine, Ali (2014),‖Thermoelastic Analysis of Disk Brakes Rotor‖ , American journal of mechanical engineering, Vol.2, No.4: pp 103-113.