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Static structural analysis of brake disc for FSAE vehicle

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ABSTRACT

The paper presents the design and analysis of disc brake for FSAE competitions. Finite element analysis to evaluate the performance under severe braking conditions by comparing two materials. Grey Cast iron and stainless-steel are used as disc brake materials. DS Solidworks 2020 and ANSYS 19.2 is used to design and carry out the analysis for determining the distribution of forces, variation of stresses and deformation across the disc brake. Most reliable and efficient material of disc brake which can survive severe braking conditions which are required in FSAE competitions is determined. A static structural analysis has been carried out using the axis symmetric finite elements. To get appropriate results the model is divided into discreate elements, so that the forces are applied effectively in each region.

***Keywords**: Disc Brake, Grey Cast iron, Stainless steel, FSAE, Solidworks, Ansys*

1) INTRODUCTION

Braking system is one of the important subsystems of a vehicle. Brakes are used to stop the motion of the moving vehicle or control its speed. They are required to stop the vehicle within the smallest possible distance, and it is done by converting kinetic energy of the vehicle into heat energy by friction. The frictional forces produced between road and tire are induced by brake to stop, control, and prevent the motion. The braking system should be efficient and effective to the vehicle as it should not disturb the comfort of the driver when it applies a pedal effort. It should create enough deceleration to stop the vehicle as soon as the pedal is pushed forward, with minimum effort and friction which causes heat should be dissipated effectively in the surrounding atmosphere. Brakes are of three types i.e., Mechanical, hydraulic, or pneumatic. Modern cars mostly use hydraulic brakes. Hydraulic brakes use an enclosed fluid to transmit the pedal force to stop the vehicle. Disc brakes are used in FSAE cars. Proper performance of the braking system by following the protocol of the FSAE cars of high speed is one of its advantages. The disc brake is a device for slowing or stopping the rotation of a wheel while it is in motion. To stop the wheel, friction material in the form of brake pads is forced against both sides of the disc.

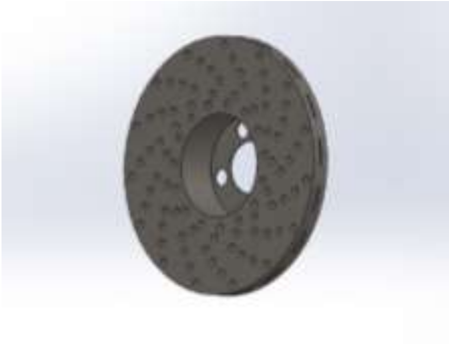
The mechanical and physical properties of a disc determine its strength, life, wear and braking characteristics. Results based on finite element analysis are used to further improve the designing and material determination of the disc brake.

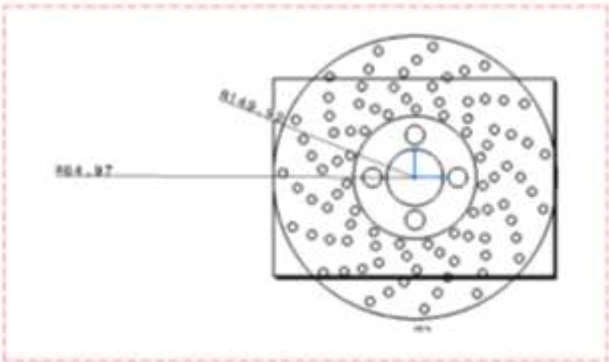
2) METHODOLOGY

A replica model of the Disc brake was created in DS Solidworks 2020 software. We analysed its performance virtually in the CAD software.
1.Considering the calculations and dimensions of the disc brake a model was created.
2. Assignment of material was given. Here, the material is Mild steel.
3. Saving the file as a STEP file or IGES file using .stp and .igs file format.

The part is now analysed in the Analysis software. Here we are using the Ansys 19.2 version.
1. We first open the Ansys workbench and select the static structural analysis option
2. Material is assigned using the engineering data option. Structural steel being the default material we change it by selecting the Mild steel material from General Material category.
3. Geometry is imported

4. Meshing is done using different meshing options, respective of the orientation
5. In static structural, we have applied pressure, fixed support, and rotational velocity.
6. In the solution, we solved the geometry for total deformation, directional deformation, Maximum strain, and stress.





3) CALCULATIONS

Total vehicle mass=M =230 kg
Static rear axle load =Mr = 103.5kg
Static front axle load=Mf = M - Mr=126.5
$\Psi = Mr \div M$
$\Psi = 0.44$
Ψ = static axle load distribution

Relative Centre of Gravity Height
$X= h \div Wb$
X= 0.1937
Where, h = vertical distance from C of G to ground on the level (m)
Wb = wheel base
X = relative centre of gravity height

$Mfdyn= ((1- \Psi) +X.a)\ M$
Where:
Mfdyn = Dynamic weight transfer on front wheel
a = deceleration (g)
M = total vehicle mass (kg)
Mfdyn on front wheel=155.53
Mfdyn on rear wheel=74.47

Wheel Lock:
$Fa =Mwdyn * \mu r *g$
Where:
Fa = total braking force possible on axle (N)
Mwdyn = dynamic axle mass
g = acceleration due to gravity (m/sec^2)
μr = coefficient of friction between road and tyre

Force required for locking of front axle :-

Force required for locking front axle =Fa=Mfdyn* μr*g=1066.4N
Force required for locking rear axle=510.9 N

Total braking force on car:-
Bf = M*a*g= 1353.78N
Torque on tyre = T= Fa*R= 177.514N.m
Torque on tyre is equal to the torque on brake disc

4) MATERIALS

Gray Cast Iron

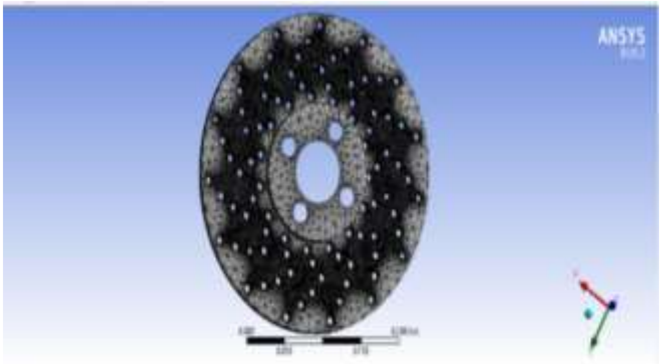
Grey Cast Iron is an alloy of Carbon and Iron. With addition of Small amounts of Silicon, Phosphorus, Manganese and Sulfur. It has high compressive strength and is highly resistant to deformation. It can be remould into complex structures and low cost. It is one of the most widely used alloys.

Stainless steel

Stainless steel is selected primarily for their heat resistant and corosion properties. All stainless steels contain principally iron and a minimum of 10.5% chromium. At this level, chromium reacts with oxygen and moisture in the environment to form a protective, adherent, and coherent, oxide film that envelops the entire surface of the material. The passive layer on stainless steels exhibits a truly remarkable property: when damaged (e.g., abraded), its self-repairs as chromium in the steel reacts rapidly with oxygen and moisture in the environment to reform the oxide layer.

MATERIAL	STAINLESS STEEL	GREY CAST IRON
DESNSITY	7750 kg/m³	7200 kg/m³
YOUNG'S MODULUS	1.93e+11 Pa	1.1e+11 Pa
THERMAL CONDUCTIVITY	15.1 W/m·°C	52 W/m·°C
SPECIFIC HEAT	480 J/kg·°C	447 J/kg·°C
TENSILE YEILD STRENGTH	2.07e+08 Pa	0 Pa
TENSILE ULTIMATE STRENGTH	5.86e+08 Pa	2.4e+08 Pa

5) MESHING:



Meshing is basically division of the model into discreate fragments. It helps in identifying the forces, deformation, various physical and thermal properties acting on a particular area of the part. It serves accuracy, convergence, and speed of the solution. All these factors depend on type of mesh we apply on the model. More accurate the mesh is on area more accurate will be the solution. And we will get more précised values as results. The type of mesh considered here is tetrahedron mesh.

Element Order	Linear
Transition	Fast
Span Angle Center	Fine
Initial Size Seed	Assembly
Bounding Box Diagonal	0.42769 m
Average Surface Area	7.308e-004 m²
Minimum Edge Length	6.0402e-006 m
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Nodes	61529

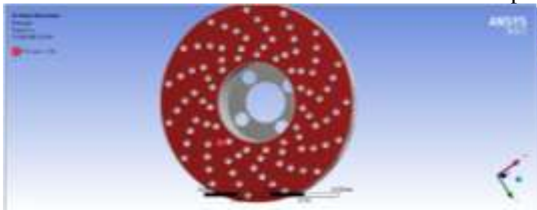
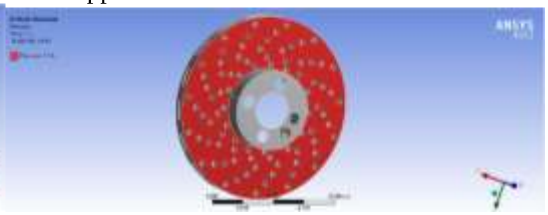
Elements	220278
Method	Tetrahedron

6) ELEMENTS OF THE STATIC STRUCTURAL ANALYSIS

Three types of elements such as pressure, fixed support and rotational velocity has been applied to the model. These factors come into consideration in when considering in braking scenario of the vehicle.

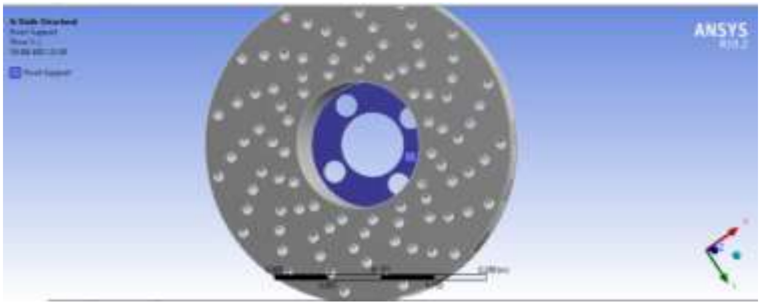
a) Pressure

Pressure is applied on both the surfaces of the disc brake. It is the pressure applied between the brake disc and brake pad. Nominal pressure applied on the disc brake is from 0 to 10P. Hence the pressure applied is 10Pa.

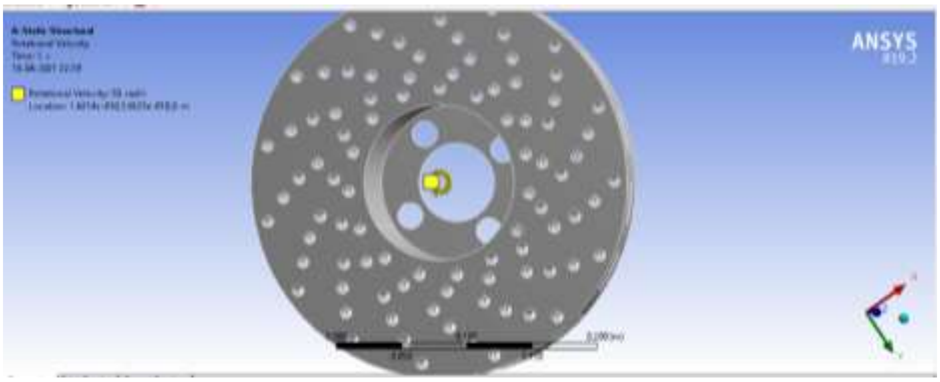
b) Fixed Support

The brake disc is bolted to the knuckle of the wheel. The brake disc is therefore firmly aligned inside the wheel assembly. Hence a fixed support is applied on the inner part of the disc.



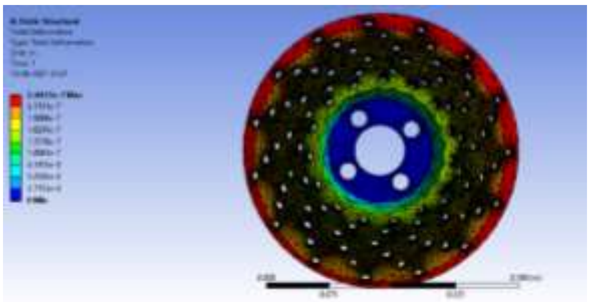
c) Rotational velocity

As the wheel moves the brake disc which is aligned to the hub also moves hence it retains a rotational velocity along its axis. A rotational velocity is applied along the centre of the disc.

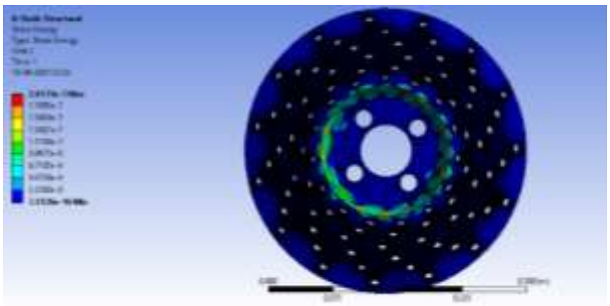


7) SOLUTION

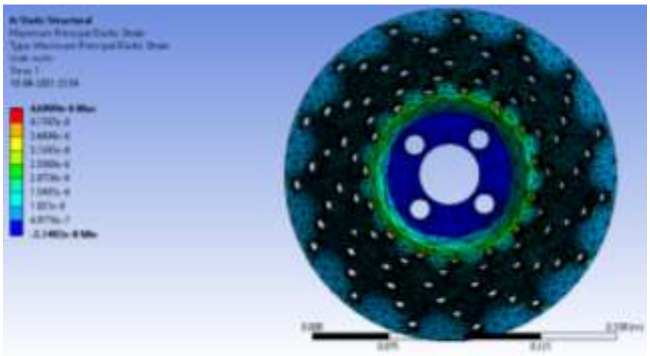
Due to various elements applied on the disc, it tends towards the total deformation, stress is applied, there is a strain in the modal and even the strain energy is being calculated of stainless steel and gray cast iron material respectively.



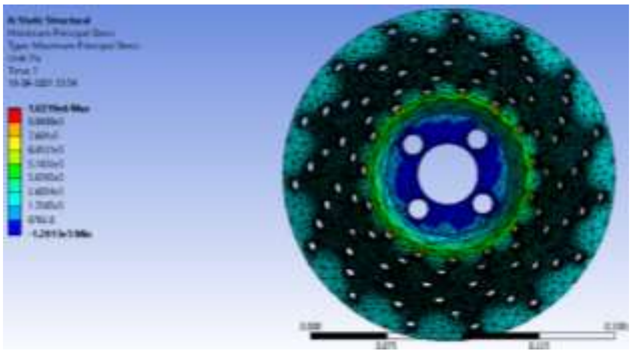
Total deformation



Stainless steel.



Maximum strain

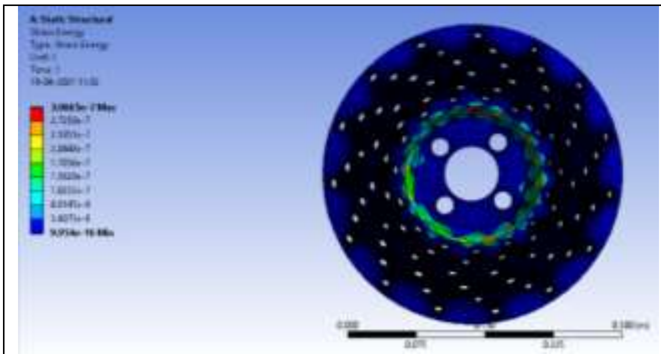


Maximum stress

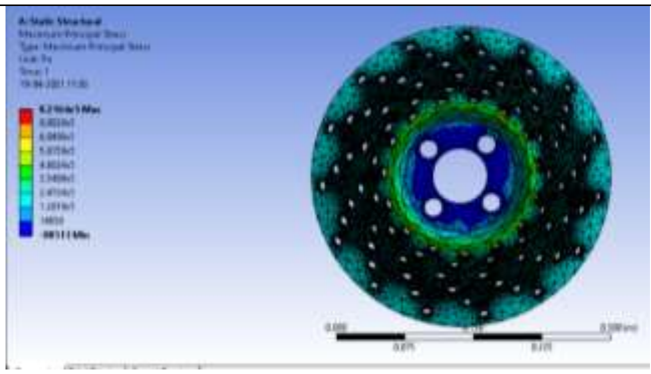
	Total deformation	Strain energy	Maximum strain	Maximum stress
Minimum	0. m	8.8961e-016 J	-2.7874e-008 m/m	-1.2532e+005 Pa
Maximum	2.4987e-007 m	2.037e-007 J	4.7954e-006 m/m	1.0181e+006 Pa
Average	1.6642e-007 m		1.1392e-006 m/m	2.3328e+005 Pa

I.**Gray cast iron**:

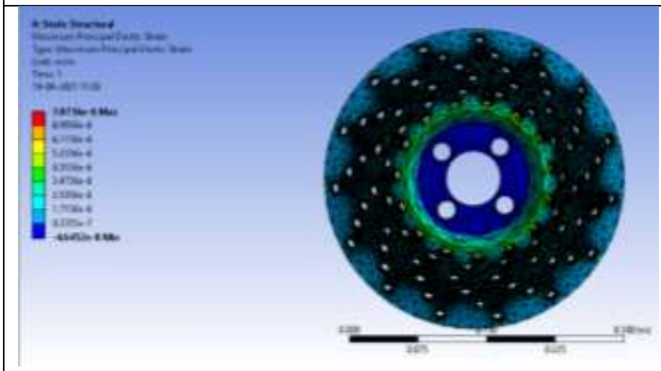
	Total deformation	Strain energy	Maximum strain	Maximum stress
Minimum	0. m	9.954e-016 J	-4.6452e-008 m/m	-98513 Pa
Maximum	4.0788e-007 m	3.0665e-007 J	7.8736e-006 m/m	9.2164e+005 Pa
Average	2.713e-007 m		1.8699e-006 m/m	2.1664e+005 Pa

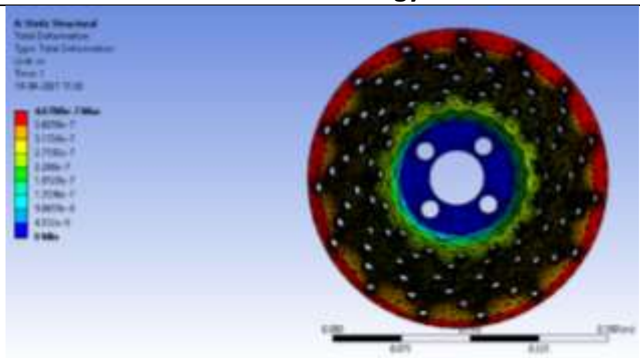


Total deformation



Strain energy





8) CONCLUSION

The most used disc brakes are made up of Grey Cast iron. The fuel consumption is high due to its heavy weight. So, weight reduction in disc brake is needed. considering the stainless steel. stainless steels are a not good as compared to grey cast iron materials for brake discs. They do not dissipate heat effectively and their low carbon content translates to poor lubricity at working temperature. Hence the FSAE vehicle requires disc brake which will sustain terrible thermal consequence at the time of severe braking conditions. Comparing the deformation, Maximum strain, Maximum stress and strain energy for conventional and proposed material indicates that Grey Cast iron satisfies the requirement for disc brake application. It is concluded grey cast iron can be used in FSAE as a replacement to stainless steel.

9) ACKNOWLEDGEMENT

We would like to thank Team Vishwaracers for allowing me to use their data for the analysis done in this paper.

10) REFERENCES

[1] Utz von Wagner, (2011) Influence of dynamic brake pad properties on automotive disc brakeSqueal, PAMM,vol 11, Issue 1, Paper 345-346.
[2] Joe Y.G. Cha, Analysis of disc brake instability due to friction induced vibration, International of automotive technology, vol 9, No 2, PP 169-171.
[3] https://www.irjet.net/archives/V5/i1/IRJET-V5I1157.pdf
[4] Design and structural in automobile-dakhil.full

