Design and Analysis of Brake Component

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Abstract - The performance and success of any vehicle depend on the ability of its components to function properly under any conditions such as wet track, dry track, and off-road terrains. The performance of the vehicle can further be improved by making the components more robust along with the proper reduction in their weight. The safe operation of any vehicle requires constant adjustments of its speed under changing traffic conditions and the brake disc is an important component for the deceleration and maintaining the speed of a vehicle under control which includes stopping. This research paper studies an optimized design of the brake disc which aims at reducing weight and maintaining the strength along with reducing the deformation at higher temperatures as compared to the OEM available in the market. The brake disc is being modelled in SOLIDWORKS and analysed via FEA in ANSYS for static and thermal loads

1. INTRODUCTION

Brake is a component used to deaccelerate a vehicle. Main components of brake are Brake pedal, master cylinder, hydraulic pressure sensors, the brake hoses, hydraulic control unit (ECU), caliper and disk. Brake pedal designing plays a very important factor in the force analysis of master cylinder as there is always a space constraint in designing an ATV resulting, that driver will not able to apply force on pedal such that on regular vehicles. During brake pedal design space constraint and resting position of a driver should be comfortable for applying force sufficient to drive master cylinder to its full stroke.

2. LITERATURE REVIEW

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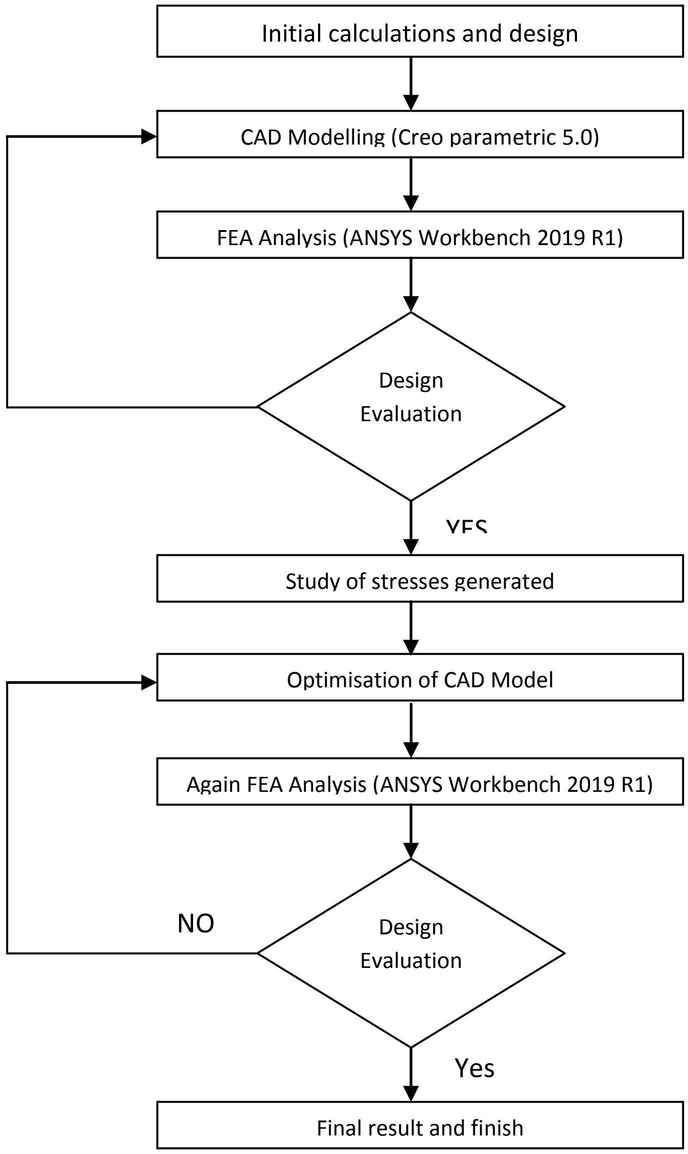
3. METHODOLOGY

This study is completed in 2 parts. First part covers the modelling and analysis of stress generated in the component, second part covers the study of stresses and optimisation of the brake pedal through the concept of biomimicry. CAD model of the brake pedal is developed in Solidworks and the FEA analysis has been carried out in ANSYS Workbench 2019 R1.

Approach of this study has been show in Fig-1



4. DESIGN: CALCULATIONS

××Calculation for Deacceleration××

$V^2 - U^2 = 2as$

$0 = 16.67^2 + 2a \times 8$

$-16a = 277.556$

$a = -17.34\ m/s^2$

××Calculation for Stopping time××

$V = U + at$

$0 = 16.67 - 17.34\ t$

$$t = \frac{16.67}{17.34}$$

t = 0.96 sec

Calculation for weight distribution and required braking force

R_F = W × (a + coefficient of friction *h) ×cos ($\frac{b}{h}$)

$$= 2452.5 \times \frac{794.26+0.7\times514.85}{1524}$$

R_F = 1858.13N

MASS ON FRONT AXLE DURING DYNAMIC CONDITION

$$= \frac{1858.13}{9.81} = 189.41 \text{ kg}$$

Mass transfer on front axle during braking = 189.41 kg

Front braking force required for front axle =

189.41 × 17.34 = 3284.36N

Force required for each wheel = $\frac{3284.36}{2}$

= 1642.18 N

Torque required for each wheel = $F_{Front\ wheel}$ × Wheel radius

= 1642.18 × 241.3

= 396.25 N m

$T_{Front\ wheel} = T_{Front\ rotor}$

$T_{Front\ wheel} = F_{rotor} \times$ rotor radius

$$F_{Rotor} = \frac{T\ Front\ rotor}{rotor\ radius}$$

$$= \frac{396.25}{0.1092}$$

F_{rotor} = 3635.32 N

5. MATERIAL SELECTION

The brake pedals are made from different materials such cast iron, aluminium, and mild steel. A detailed study was carried out to select the most suitable material depending on the factors such as availability of material, Yield strength, weight, cost, weldability. AL-7075 T6 was selected over Grey based on availability, cost, Yield strength and fatigue strength.

Properties	Values
Density	2.81 g/cc
Ultimate Tensile Strength	572 M Pa
Tensile Yield Strength	503 M Pa
Elongation at Break	11%

6. DESIGN: CAD MODELLING

The initial CAD model of the brake pedal has been created in Solidworks 2019. It consists of mounting points for itself and 2 master cylinders. The design processes were started with defining and evaluating all the design constraints.

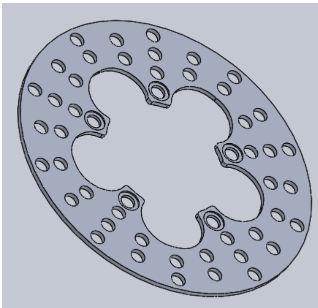


Fig 1: - Model Of Disc Brake

7. MESHING

The CAD model is imported into ANSYS Workbench 2019 R1. The automatic mesh with size 1mm is used for this study.

Nodes	134283
Elements	73230

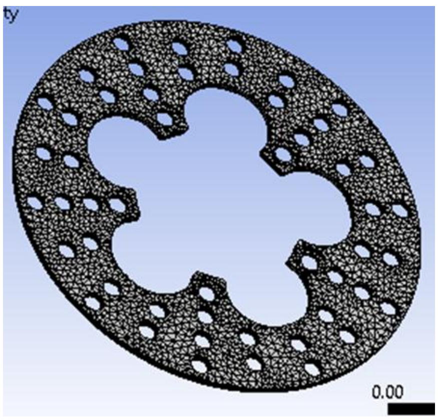


Fig -2: Mesh Model

8. ANALYSIS

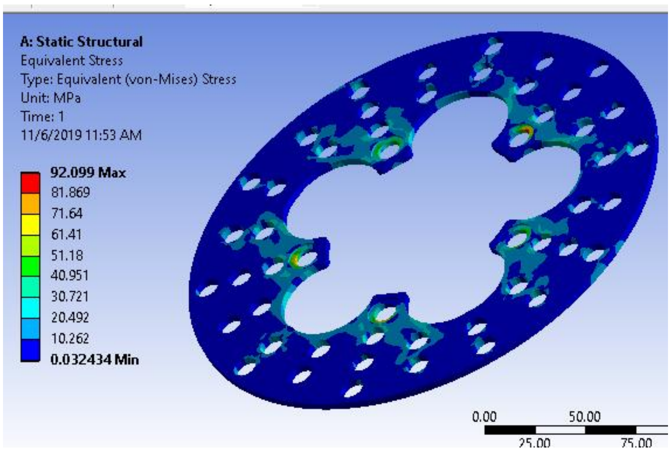


Figure :- Equivalent Stress

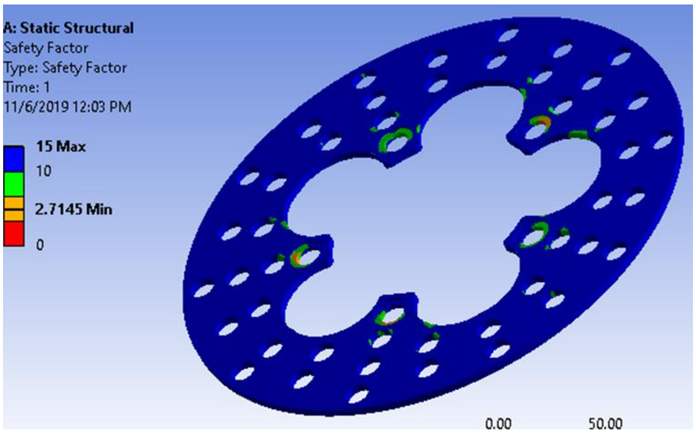


Figure :- Factor of Safety

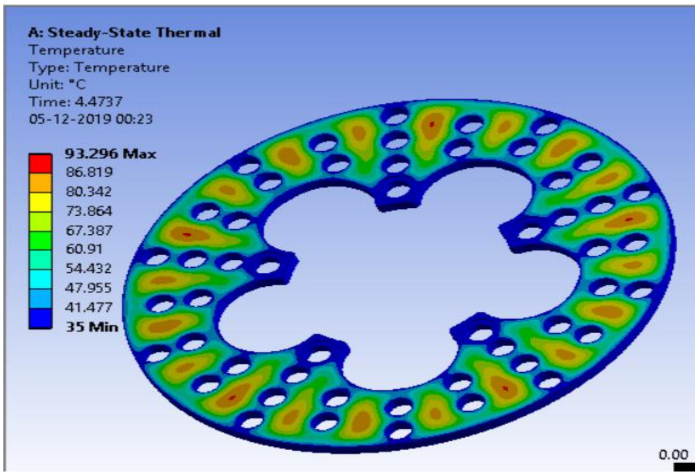
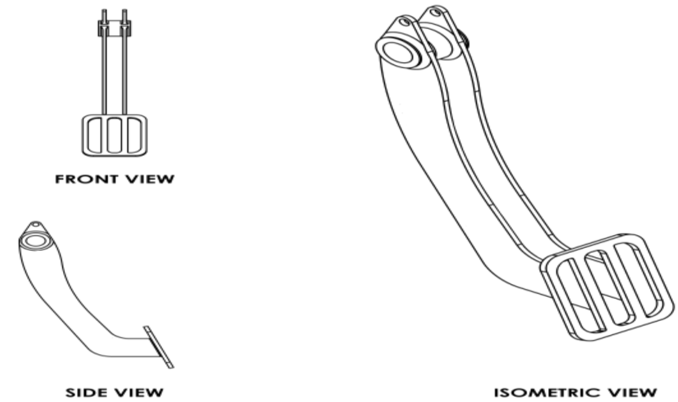


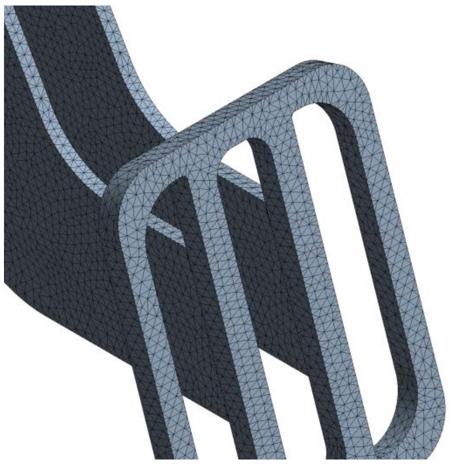
Figure:- Steady State Thermal

9. DESIGN: INITIAL CAD MODELLING: Brake Pedal

The initial CAD model of the brake pedal has been created in PTC Creo Parametric 5.0. It consists of mounting points for itself and 2 master cylinders. The design processes were started with defining and evaluating all the design constraints. The mode of manufacturing for this brake pedal is welding of laser cut parts. The geometry also includes fillets of 4mm around the footrest and pivot region to represent weld bead. Initial CAD model of the brake pedal is

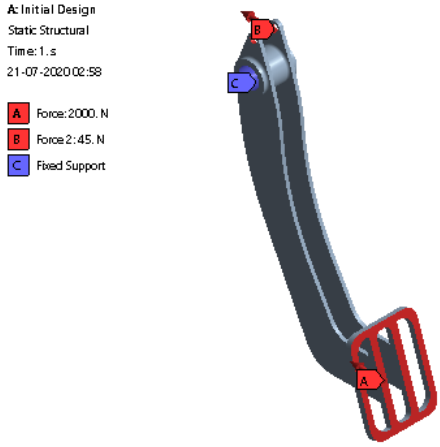


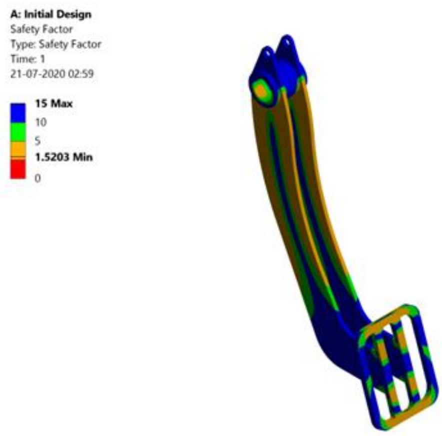
Nodes	134283
Elements	73230

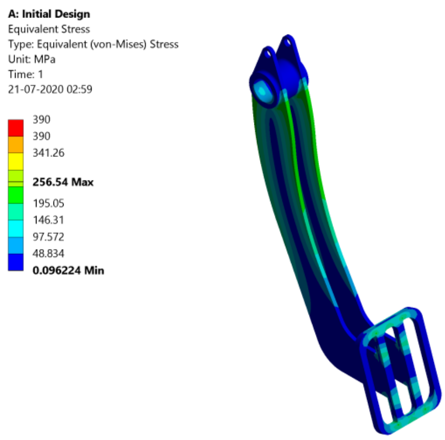


Boundary conditions:

- A of 2000N is applied normally by driver in –x axis on the foot rest.
- The pivot point is fixed.
- Force of 45N is applied in –x axis to simulate the force presented by master cylinders.



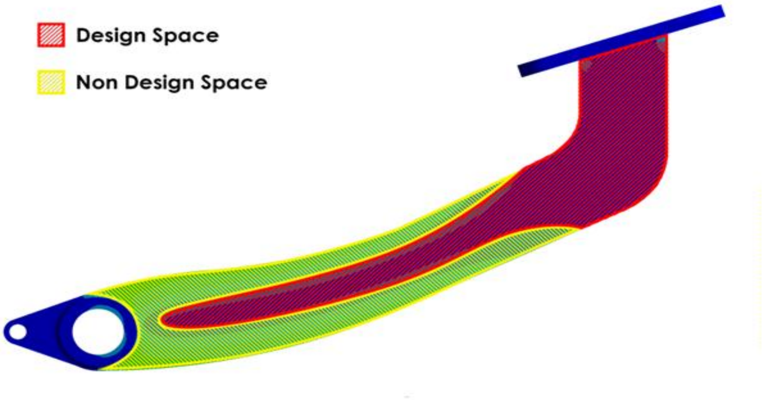




Study of generated stresses:

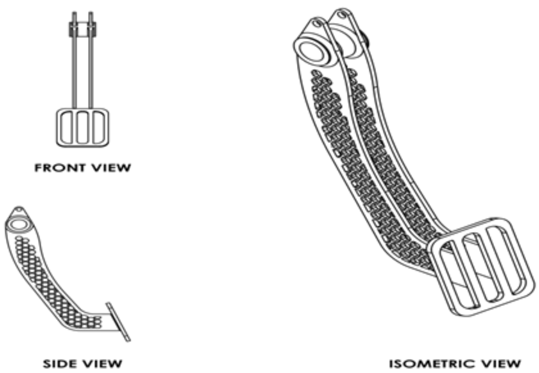
The second part of this research includes the optimisation of brake pedal to minimise the weight of the component and to remove extra material. The inspiration for optimisation was drawn from a honeycomb structure. A honeycomb structure provides rigidity and efficient stress distribution along with minimal weight.

The von-Mises stresses and safety factor obtained from the analysis are used to map the region where the optimisation study can be carried out in order to remove extra material. The region where the optimisation study is needed is shown in Fig*. The Red region defines the design space where the optimisation study is carried out; the stresses in this region are low which contributes to high safety factor which in turn means that there is excess material available in this region. The yellow region encloses the space where high stresses are being generated thus no optimisation study is required in this region.



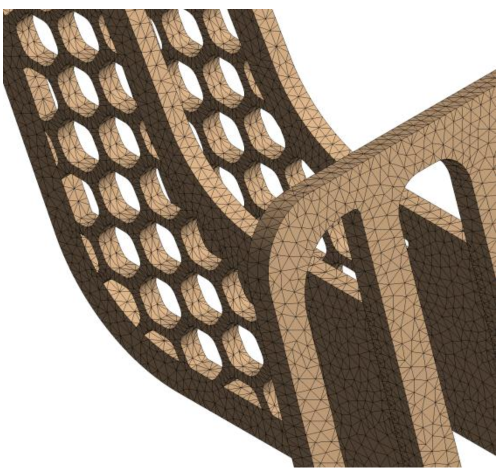
DESIGN: OPTIMISATION CAD MODELLING

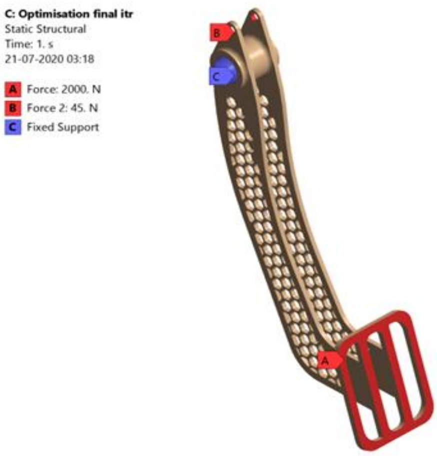
The optimised CAD model of the brake pedal has been created in PTC Creo Parametric 5.0. It consists of mounting points for itself and 2 master cylinders. The Design space has been optimised with a hexagonal lattice structure for weight reduction. Optimised CAD model of the brake pedal is shown in Fig*\



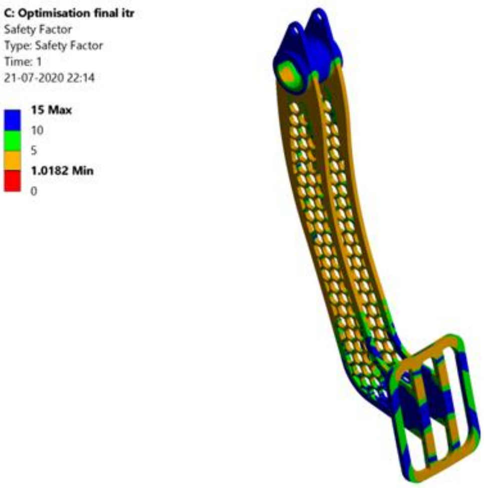
ANALYSIS:

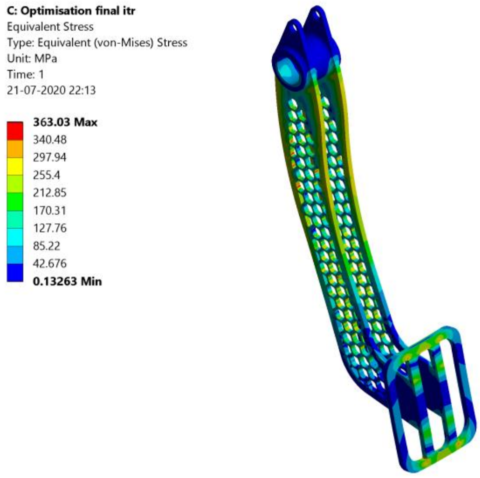
The Mesh and boundary conditions are kept same for the second analysis.



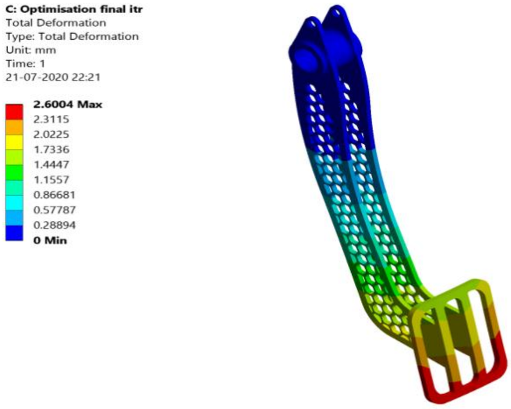


Results:

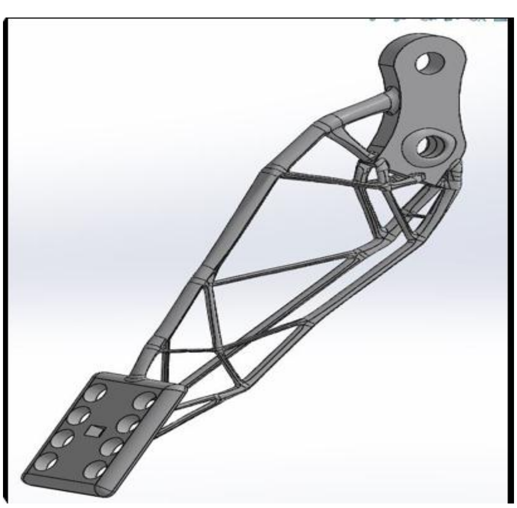


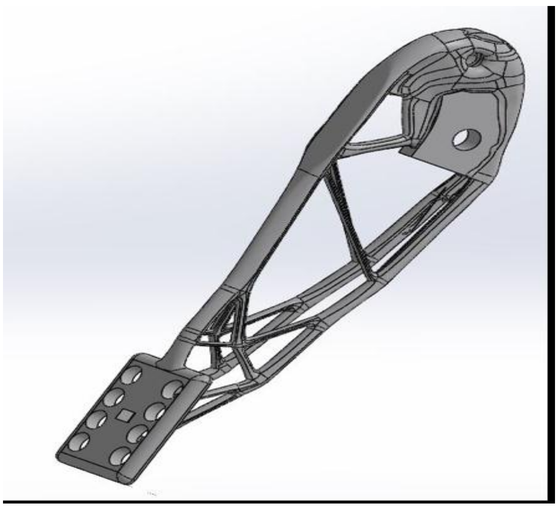


Maximum Equivalent von-Mises Stress = 363 Mpa Minimum Safety Factor = 1.02



Maximum displacement = 2.6mm





Mass – 74 grams Mass – 122 grams

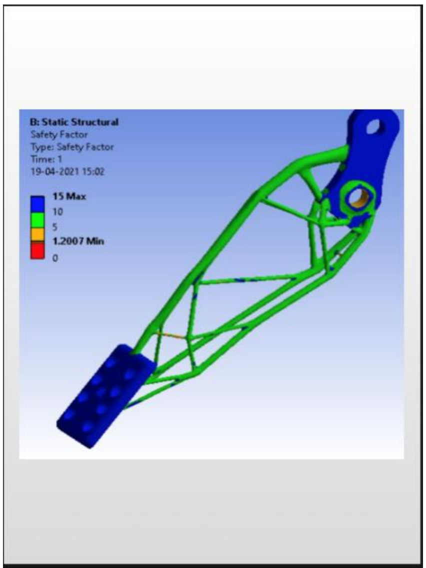


Figure: - Factor Of Safety

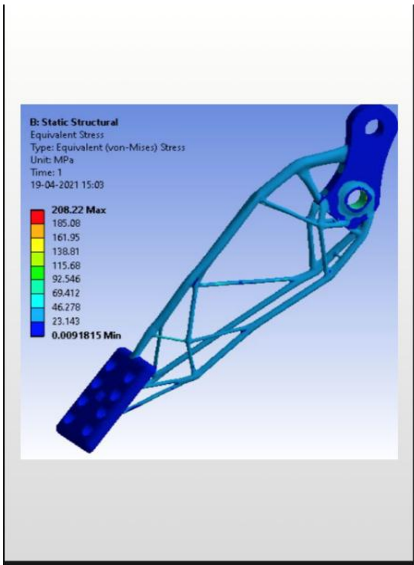


Figure: - Equivalent Stress

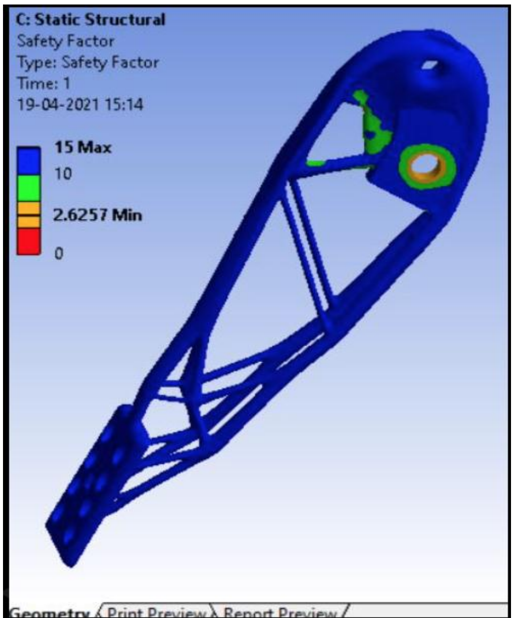


Figure: - Factor Of Safety

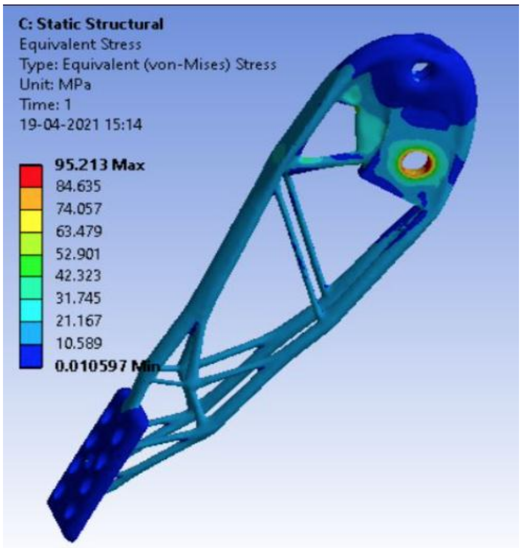


Figure: - Equivalent Stress

10. CONCLUSION

1. Upon comparison it was observed that the design 2 of Generative design Model has the highest factor of safety for similar working conditions i.e. "2.6257" and weight of the brake pedal was reduced from "256 grams" to "122 grams" which is "52.34%" weight reduction.

2. All stresses are under allowable stress in structural analysis.

3. From the set of values, the best outcomes are found at deformation is 0.014503 mm, stress 92.09MPa and temperature at 93.296 C on AL-7075 T6 with 5 mm thickness

11. REFERENCES

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