Design and Analysis of Braking and Steering of a Go-Kart

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Abstract - Weight decrease is one of prime problems for a vehicle. It was chosen to decrease weight ofdisc brake by material AL-7075. CAD modelling software is used for designing of disc brake, brake pedal, Steering Hub etc for fulfilment of our conditions. Conditions are required to activate braking system and all wheels locking at same time. The research paper additionallyincludes the parameter for disc, static analysis, and steady state thermal analysis dependenton different parameter. Structural analysis is done because of mechanical strength of material and Thermal analysis is done on the basis of heat properties of material. This research paper studies an optimized design of the braking and steering component of a Go- Kart 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.

1. INTRODUCTION

a. BRAKING

A brake is a mechanical device that utilizes retaining movement by active energy from a moving body and afterward changes over it into heat vitality. The hydraulics brake is a kind of stopping mechanism that utilizes a rotor is associated with the hub of the wheel and set of erosion material called as brake shoe is constrained generally by hydraulic poweredweight against the two sides of the rotor which makes it stop with the assistance of rubbing.The most important parameter for any vehicle is the braking system. Compared to drum brakes, disc brakes better-stopping efficiency. All the elements of the braking system play animportant role in any vehicle, its functions include slowing down of the vehicle, maintaining the speed during downward operation, and also holding the vehicle after it has come to complete stop this is done by the dissipation of mechanical energy of the body into the heatenergy by the frictional forces. In the hydraulic braking system, the disc is being mounted onthe wheel hub which moves along with the wheel. At the time pressing brake pedal, the push rod connected to the hydraulic brake cylinder pressurize the hydraulic fluid with the help of a piston to a high extent by taking the advantage of the pedal ratio which is defined as the ratio of the leverage of your clutch applies to the hydraulic brake cylinder further the brake fluid passes through the brake hoses which are connected to the brake caliper.

b. STEERING

The mechanism is of vital a part of the dynamic style of any automobile to facilitate a swish amendment of directions and build use of the tires ability to get lateral forces to the very best extent. An athletics driver's sensory inputs provide visual, tactile, and mechanicalphenomenon data utilized in developing a "feel" for automotive handling and performance. This feedback is critical in sanctimonies the driving force to extract most performance from the automobile. thence the steering is a crucial feedback mechanism giving the driving forcedata on stability and directional management. The management of associate degree automobile is finished by means that of a mechanism that provides directional changes to the moving automobile. The intention of Ackermann pure mathematics is to stop the tires from slippery outward once the wheels follow around a curve whereas taking a flip. the answer for this can be that everyone wheels to own their axles settled as radii of circles witha standard center purpose. Since the rear wheels square measure fastened, this center purpose should lie on a line extended from the rear shaft. Thus, we'd like to cross the front shaft to the present line at the common center purpose. whereas steering, the inner wheel angle is larger than outer wheel angle. Thus, for getting totally different results we'd like to vary the parameters so as to get desired steering pure mathematics.

2. Literature Review

K.Sowjanya and S.Suresh [1] have presented research paper which gives an overview of analysis of disc brakes. Brakes are mechanism system which is used to retard motion of moving body. Disc of brakes is made of cast iron or, aluminium composite.

These areselected by running several tests on software likes Pro/E (Creo- Parametric) for solid modelling and static analysis are done by CAD/CAE softwares.

Neeraj Singh at el [2] have worked on research paper which focuses around structure and test examination of braking mechanism for off-road condition for BAJA 2016. Every part of braking mechanism was designed on CATIA-V5 though investigating and temperature analysis was finished by ANSYS16.

Vivek Singh Negi at el [3] has been examines thoughts for utilizing different parameter in thesystems, structure factors and rationale behind the choosing right estimate of the factors. Structure of braking system mechanism comprises of evaluating huge number of a situationsand utilizing to accomplish the ideal, yet compelling braking. Information identified regarding to utilized to remove normal estimations of design parameters, makinghypothetical counts as reasonable as could be expected under circumstances.

Kush Soni at el [4] has been done the part determination of braking system mechanism is talked about. Different calculation of braking power, braking torque and brake inclination areappearing. Likewise, the safety of utilizing bike rotor is approved by calculation and thermal investigation. Our essential point was to think of a braking system mechanism that is straightforward and has an advanced load along being dependable. According to the rule book of SAEINDIA BAJA 2020, it was obligatory for the system to comprise of two independent operated hydraulic circuits. Likewise, all the four wheels must be lock at the same timesimultaneously.

Sanket Nawade (5) They concluded that after the Software Computation Analysis and Numerical Analysis, & found the approximate same deformation in chassis which is negligible. Also FEA analysis is successfully carried out on CAD model to determine Equivalent Stresses and Factor of Safety. Also found the Factor of Safety greater than 1, thatconclude their chassis design is safe and the material used that is AISI 4130 is best material for GoKart Chassis.

Mohd Anwar (6) In this Research Paper manual mechanical linkages steering system is not used in heavy weight vehicles due to high axle loads, although it is simple in design and easyto manufacture, therefore it is commonly used in light weight vehicles. The values calculatedin the paper may differ practically due to steering linkages error or due to improper steeringgeometry, so these values are useful to understand the interdependency of the quantities on each other and to design a ideal manual mechanical linkages system for the vehicle.

PRABHUDATTA DAS (7) The report discussed about the design and fabrication of a go-kart vehicle giving special attention to improvement of suspension system and dynamics over lastmodel. The first half of the report discusses about the nodal analysis of previous model and noting down the points of review and limitations in old model. The other half of the report discusses about a whole new design which tries to eliminate the defects of old design and also implementing the positivity of old design in the new one. It also discusses about new design procedure and the transmission, suspension and steering system of the new go-kart model.

Arshad Khan (8) In this paper, The steering mechanism used which is Ackermann steering geometry is discussed with the steer cases and is explained in simple quadrilateral notation form with terms considered in mechanism and the assumptions made during the solution ofthe Ackermann steering geometry problems. The analysis of the steering system components through various software's can be performed which determines the stresses, loads and deformation of the steering system from which the design engineers can predict the safety of the system and can also be modified and minimization of the errors in the systems can be done.

Mr. Girish Mekalke (9) This paper discussed about the design and fabrication of a go-kart vehicle giving special attention to improvement of chassis system. Thus the kart was designed using basic automobile principles. It is analyzed using finite element techniques toprove its effectiveness. Finally, an effective design for the kart is developed which can outperform the existing karts and also in the upcoming era of automobile vehicles.

Ramagiri Sai Kiran (10) In this paper model of chassis is structured in 3D CAD Modeling software which gives extraordinary adaptability to the creator and it is very easy to import for analysis in ANSYS or some other simulation software. In this study, it is clearly seen that the natural frequencies of AISI 4130 and AL-2014-T6 are higher in comparison with differentmaterial. AL-2014-T6 was selected on account of less density and high yield strength when compared to AISI 4130 along these lines, to design a go-kart, it is basic to think about the body to weight proportion.

3. Braking Calculation

Assumed and Experiment Values

PARAMETER	VALUES	Reference
Coefficient offriction (Roadand Tyre) μr	**0.8**	**Experiment**
Coefficient of static of friction (brake pad anddisc) μbp	**0.5**	**Experiment**
Front rotor diameter (RDF)	**685.8 mm 170 mm**	**Assumed**
Rear rotor diameter (RDR)	**170 mm**	**Assumed**
Mass of vehicle	**1371.6 mm**	**Assumed**

Effective brakepads area (ABP)	**0.0018338 m^2**	**Calculated**
Max velocity (v)	**12.5 m/s**	**Transmission department**
Area of piston ofmaster cylinder (AMC)	**2.85×10^{-4} m^2**	**Calculated**

Calculated Values

Wheel base (L)	**1371.6 mm**	**As per therulebook**
Wheel diameter(Front)	**533.4 mm**	**Transmission Department**
Wheel diameter(Rear)	**558.8 mm**	**Transmission Department**
Distance of CG from rear axle(a)	**685.8 mm**	**Roll Cage Department**

Calculation for weight distribution and required braking forceFront

Wheel

$$R_F = W \times (a + \text{coefficient of friction} \times h) \times \cos\left(\frac{b}{h}\right) \quad \text{-} \qquad \text{(i)}$$

From equation (i), we get R_F = 1943.98 N

Sliding force required to lock the wheel

$S_F = \mu_r \times R_F = 1555.18$ N

Braking Torque acting on front wheel - $T_F = S_F \times$ Radius of wheel = 414.76 Nm The same torque will act on rotor

$T_F = T_{ROTOR} = 414.76$ Nm - (ii)

From equation (ii), we get

Radial Force acting on rotor

$F_{RF} = (T_{ROTOR} \times 2) / R_{DF}$

$= 4879.529$ N

Force acting on brake pads

$F_{bp} = \mu_{bp} \times F_{RF} \times 2$

$= 4879.529$ N

Pressure required for pulling caliper piston out

$P_p = F_{bp} / A_{P1}$

$= 5.374$ MPa

Same Pressure will act on piston of master cylinder. Therefore, force required

$F_{MC1} = P_P \times A_{MC} = 1531.7$ N - (iii)

Rear Wheel

$R_R = W \times (L - a - \mu_r h) \cos\beta / L$ - (iv)

From equation (iv), we get

$= 655.67$ N

Sliding Force

$S_R = \mu_r \times R_R = 524.536$ N

Braking Torque acting on rear wheel

$T_R = S_R \times$ Radius of wheel

$= 146.55$ Nm

$T_R = T_{ROTOR} =$

146.55 Nm $F_{RR} =$

$(T_{ROTOR} \times 2) /$

R_{DR}

$= 1724.18$ N

Force acting on brake pads F_{bp} = $\mu_{bp} \times F_{RR} \times 2$

= 1724.18 N

Pressure required for pulling caliper piston out - $P_p = F_{bp} / A_{P2}$ = 2.14 MPa $F_{MC2} = P_P \times A_{MC}$ - (v)

= 611 N

Force required to pull piston of master cylinder

From equation (iii) and (v), we get $F_{MC} = F_{MC1} + F_{MC2}$

= 2142.69 N

Mass Required = 218.42 Kg

Pedal Ratio = 10:1

Mass required to press pedal = 21.84 Kg

4. STEERING GEOMETRY

Taking Ackermann principal of steering Ackermann principle of steering is used to clarify theequation of wheels on the inside and outside of a turn required to find out circles of various radius.

Assumptions

- 100% Ackermann steering geometry.
- Maximum road bank angle is 20°.
- Optimum kingpin inclination angle range is 4° to 8°.
- Front to rear weight ratio is 40:60.
- Taking acceleration due to gravity as 10m/s^2.

Goals: -

- To enable smooth and stable manoeuvring of the vehicle.
- To optimize the steering effort.
- Provide adjustability for parameters such as caster angle and toe.
- To select and implement the best mechanism that suits the purpose.

Geometry Considerations: -

- Camber: The camber angle is set to zero degree because we do not use suspension systemto provide dynamic camber during cornering.

- Caster: It is the angle formed by the axis of the bolt that is kingpin inclination whichconnects the stub axles to the knuckle.

- Kingpin Inclination: Due to the geometry of the stub axle the King pin offset is high, which demands large kingpin inclination to minimize scrub radius which is not feasible. Hence it is set to 0 (zero) degree.

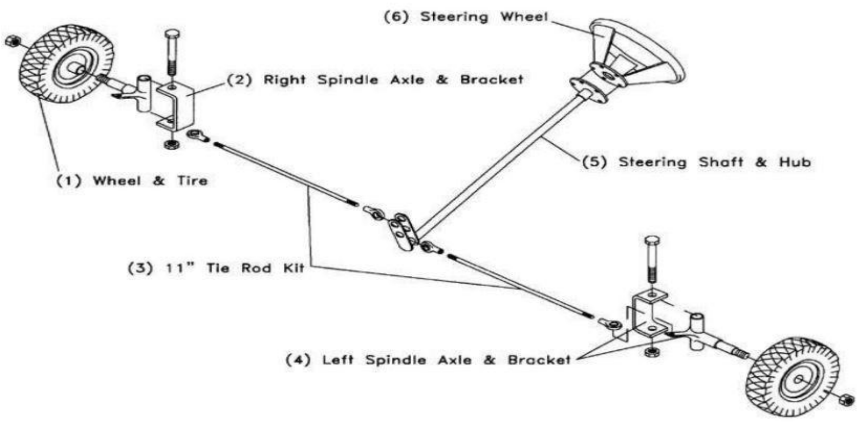


Fig :- Steering system

CALCULATIONS

Required Parameter:

I. Wheelbase (L) = 1143mm

II. II. Track width (T) = 1016mm

III. III. Assuming the turning radius (R) = 2000mm

IV. IV. Weight of the vehicle without driver (W) = 100kg

V. V. Weight ratio = 60:40

Therefore, weight on the rear tires (Wrt) = 60kg And, weight on front tires (Wft) = 40kg

A. Distance of center of gravity from rear axle (B): -

W*B = Wft*LB = Wft*L/W

B = 457.2mm = 17.99 inches

B. Inner angle (θ): -

Tan θ = L / (R*cosδ - T/2) =1143 / (2000 – 1016/2)θ = 37.45°

C. Outer angle (ϕ): -

Tan ϕ = L /(R*sinδ + T/2) = 1143 / (2000 + 1016/2)

Tan ϕ = 0.45574ϕ = 24.50°

D. Actual turning radius: -

R" = √(B2 + X2) R" = √[(457.2)2 + (2000.28)2] R" = 2051.86m

E. Ackermann angle (α): -

α = tan-1[L/(L/ Tan ϕ – T)]

α = 37.45°

F. Ackermann %: - =

θ/**α** ×100 = 37.45/37.45 × 100 = 100% geometry

5. Material Selection: Braking

Material Selection: Braking

A detailed study was done to pick the most compatible material for fabrication of the braking system. Various factors were considered while selecting the material such as availability of material with mechanical strength, elongation at break, Hardness weldability, cost etc. The material which we selected was Al-7075 T6 because of its better yield strength and ultimate tensile strength as compared to other material.

Mechanical properties of AL 7075 T6

Properties	Values
Density	2.81 g/cc
Ultimate Tensile Strength	572 MPa
Tensile Yield Strength	503 MPa

Material Selection: Steering

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. AISI 4340 wasselected over AISI 1018 on the basis of availability, cost, Yield strength and fatigue strength.

PHYSICAL PROPERTY	AISI 1018	AISI 4340
Density	7.87 g/cc	7.85 g/cc
Yield strength	370 MPa	862 MPa
Tensile strength	440 MPa	1262 MPa
Poisson's ratio	0.29	0.33

6. DESIGN: BRAKING COMPONENT

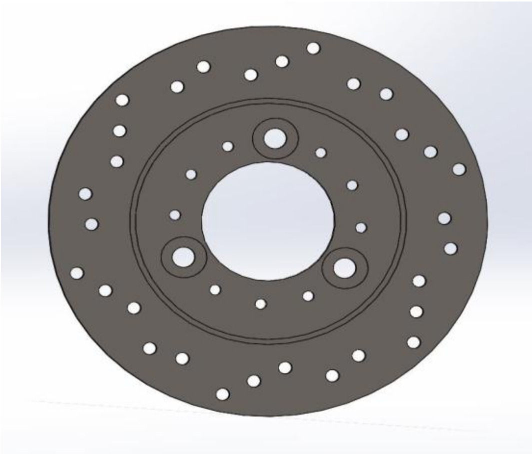


Figure: - Model of rotor

Figure: - Model of brake pedal

DESIGN: STEERING COMPONENTS

Figure: - Model of Steering wheel

7. ANALYSIS: BRAKING COMPONENTS

The design was simulated for the below conditions using following mesh parameters.

Mesh Parameters	
ELEMENT SIZE	1 mm
ELEMENT TYPE	2D
ELEMENT QUALITY	0.94
TOTAL NODES	186243
TOTAL ELEMENTS	99537

DISC BRAKE

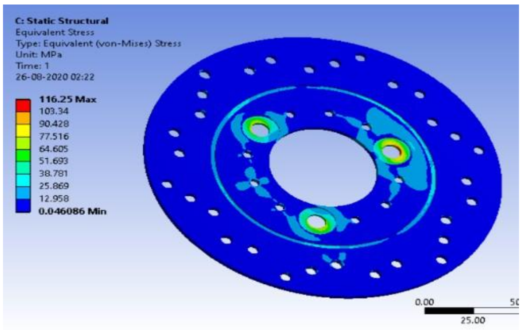


Figure: - Equivalent Stress

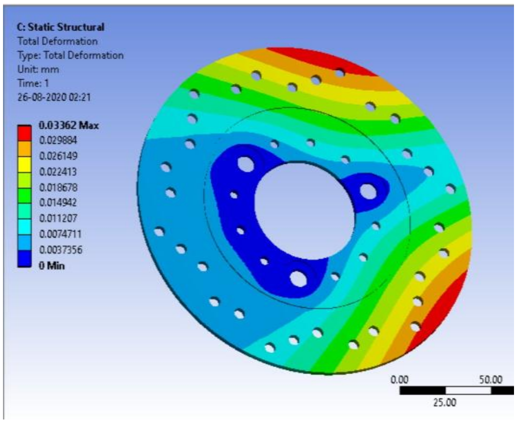


Figure: - Total Deformation

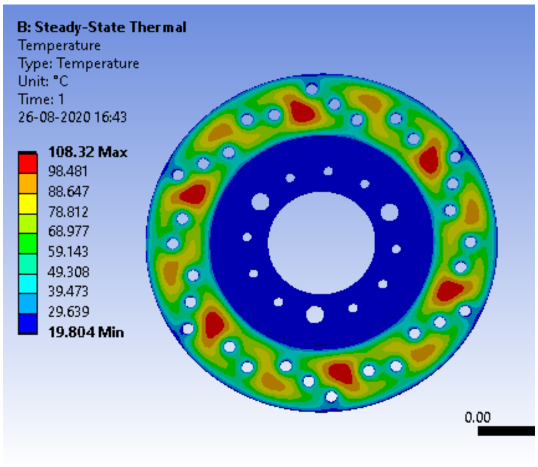


Figure: - Steady State Thermal

BRAKE PEDAL –

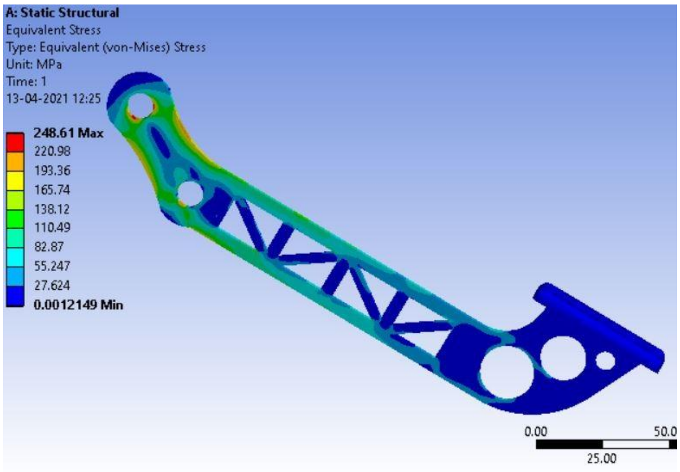


Figure: - Equivalent Stress

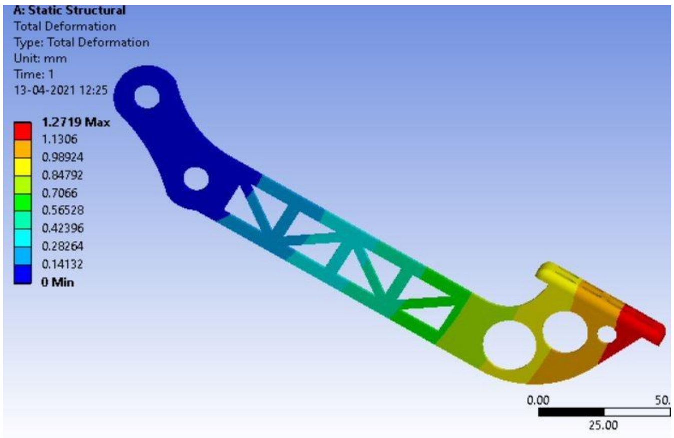


Figure: - Total Deformation

8. TOPOLOGY OPTIMIZATION

1. Brake Pedal (1st Iteration)

Specifications:

Volume = 45688.32mm3

Mass = 122 grams

Analysis Of Brake Pedal

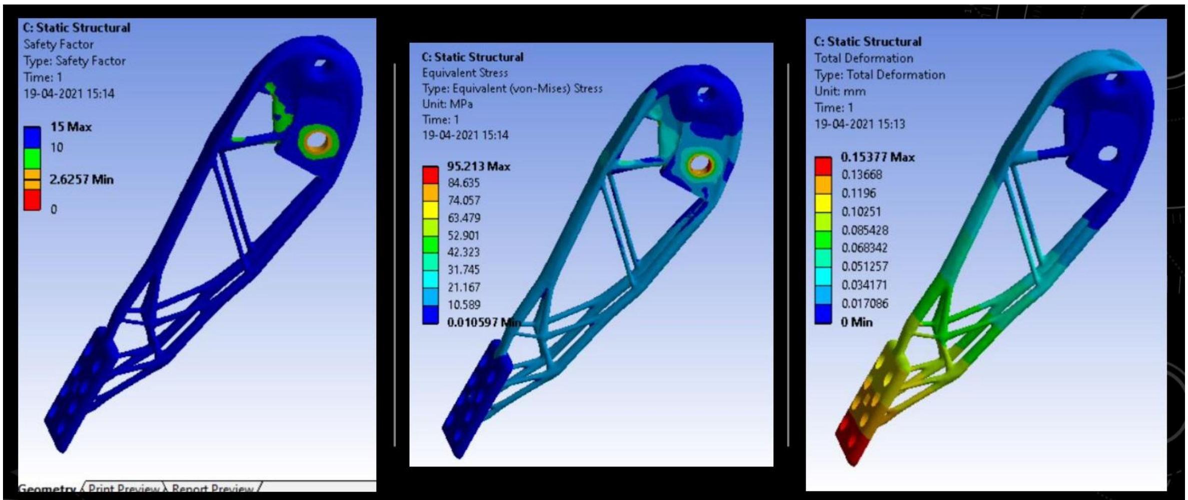


Figure: - Factor Of Safety

Figure: - Equivalent Stress

Figure: - Deformation

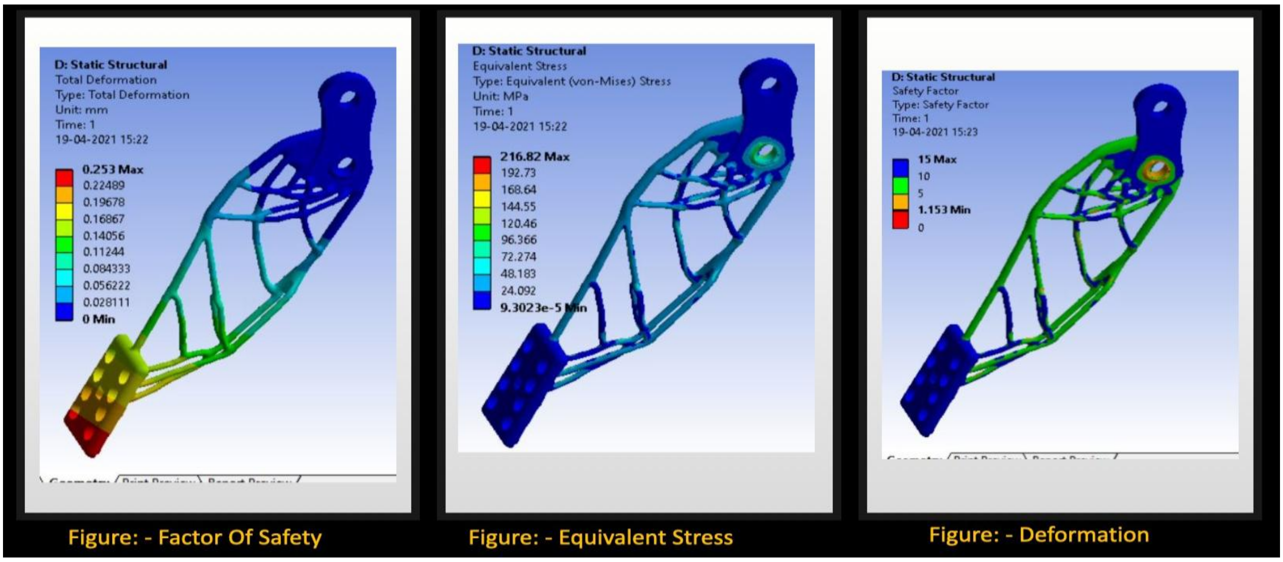
1. Brake Pedal (2nd Iteration)

Specification:

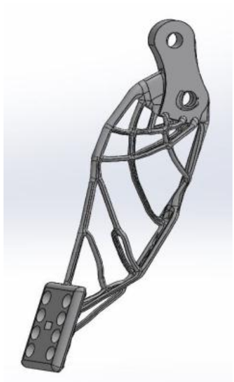
Volume = 30164.73mm^3

Mass = 81 grams

Analysis of Brake Pedal



1.Brake Pedal (3rd Iteration)



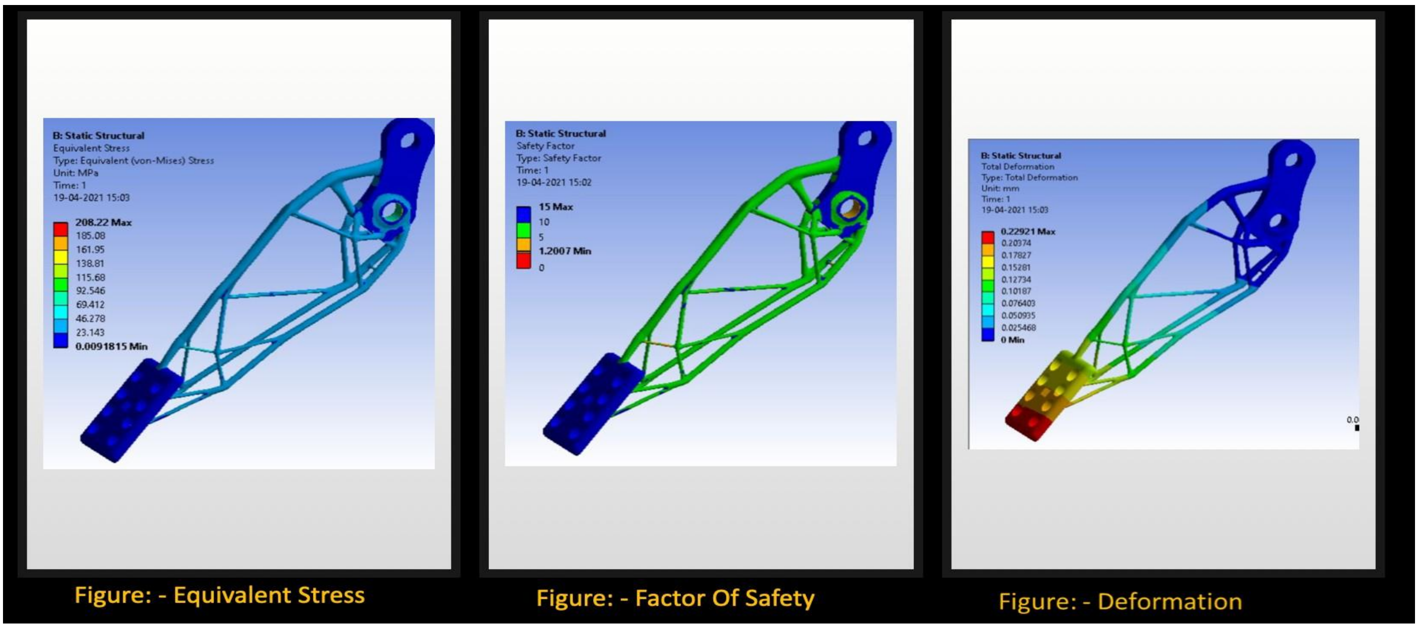
Specifications:

Volume =

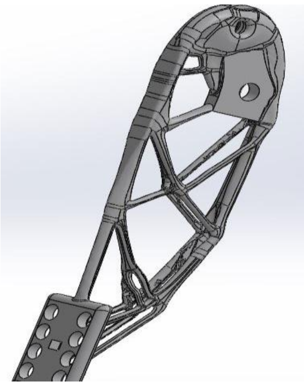
27743.82 mm3

Mass = 74 grams

Analysis of Brake Pedal



1. Brake Pedal (4th Iteration)



Specifications:

Volume = 30164.73mm3

Mass = 81 grams

Analysis of Brake Pedal

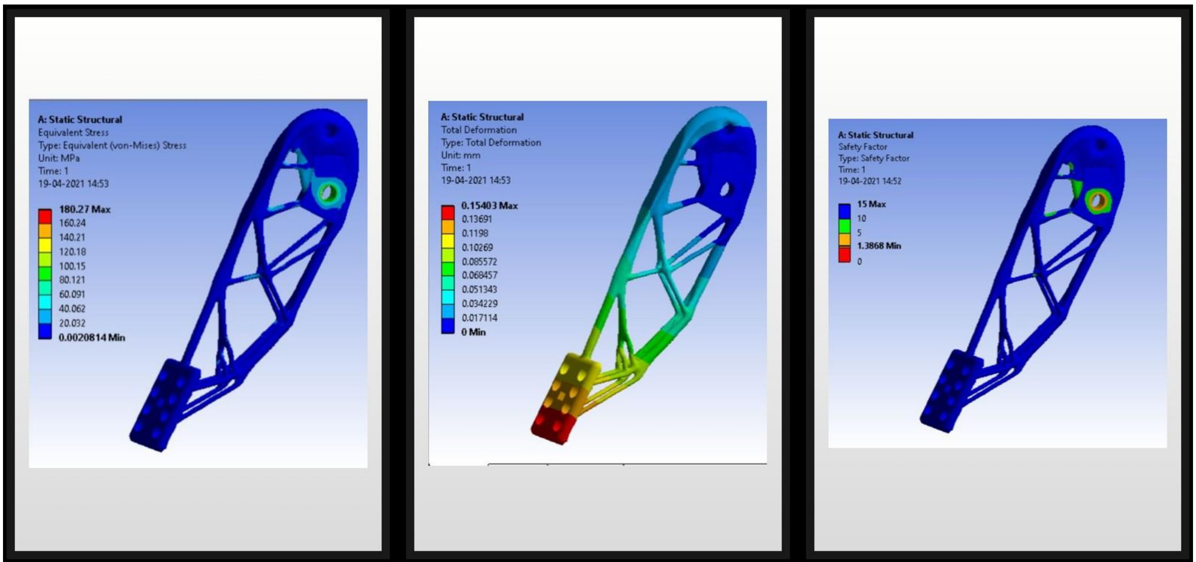
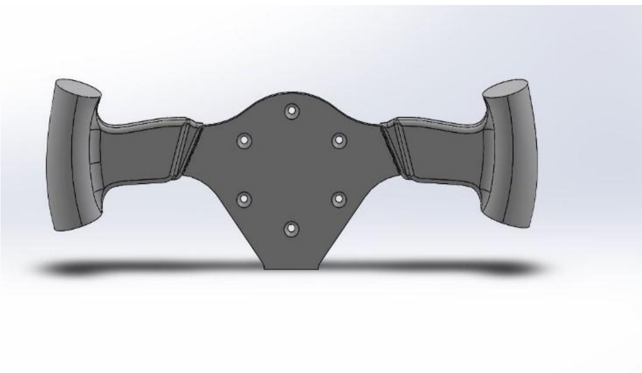


Figure: - Equivalent Stress | Figure: - Deformation | Figure: - Factor Of Safety

2. Steering Wheel



Specification:

Volume = 326637.46 mm3

Mass = 872 grams

Analysis of Steering Wheel

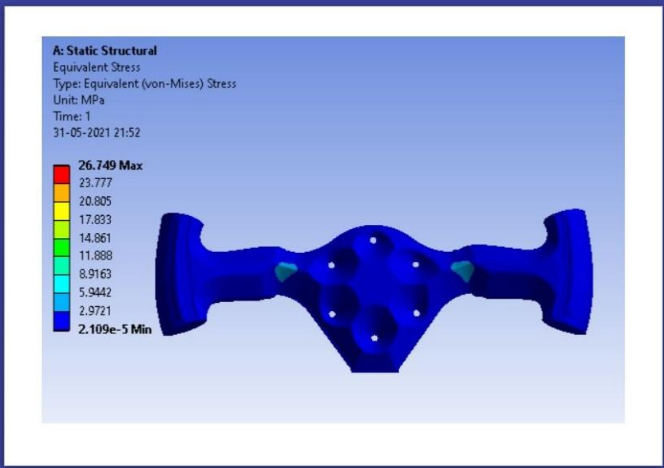


Figure: - Equivalent Stress

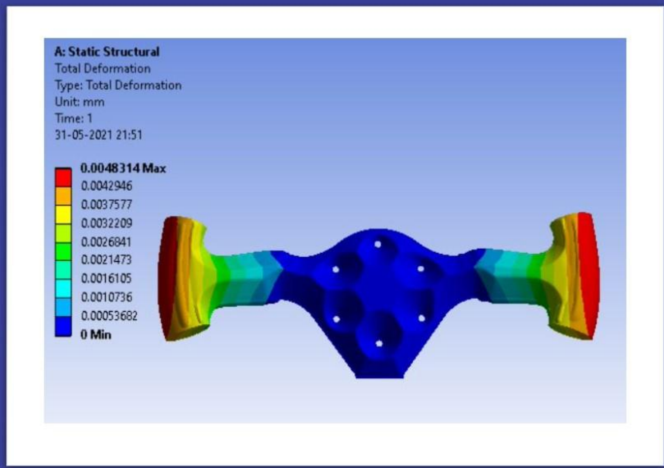
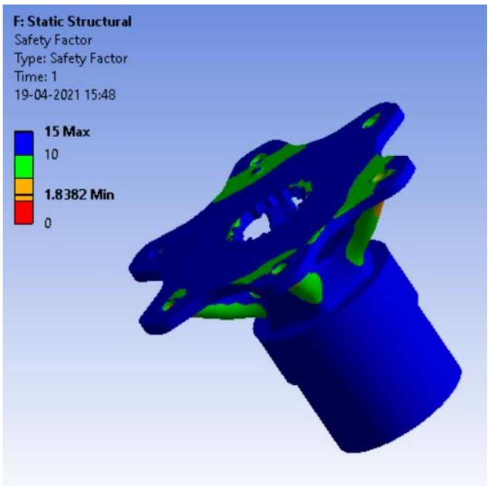


Figure: - Deformation



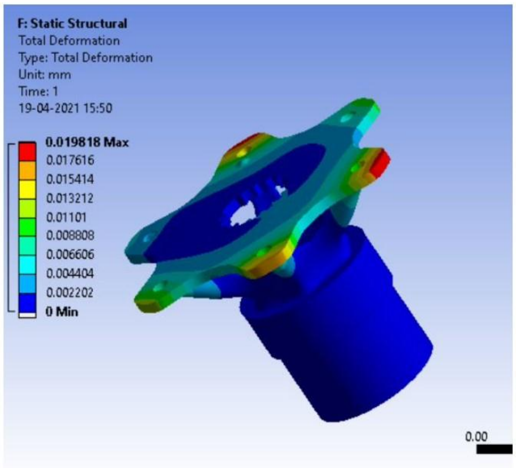
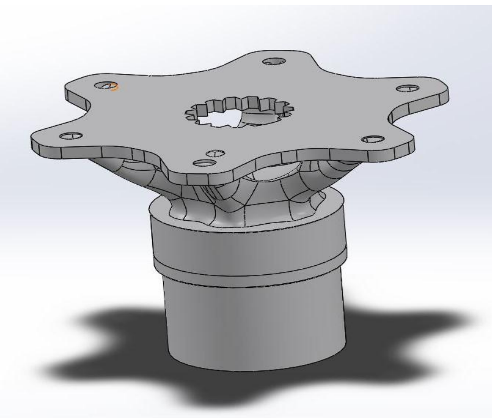


Figure: - Factor Of Safety

Figure: - Deformation

3. Steering Hub (1st Iteration)



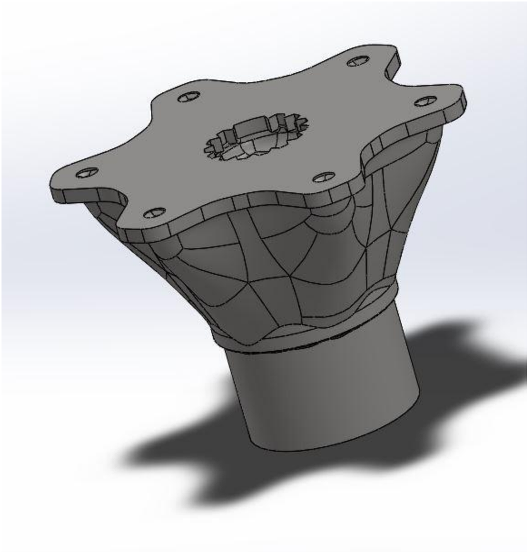
Analysis Of Steering Hub

Specification:

Volume = 54300.94 mm3

Mass = 145 gram

3. Steering Hub (2nd Iteration)



Specification:

Volume = 109316.98 mm3

Mass = 808 grams

Analysis Of Steering Hub

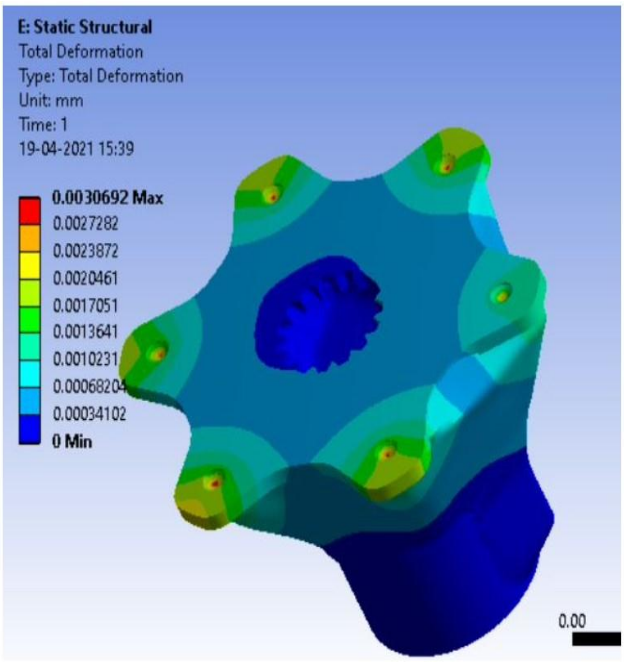


Figure: - Deformation

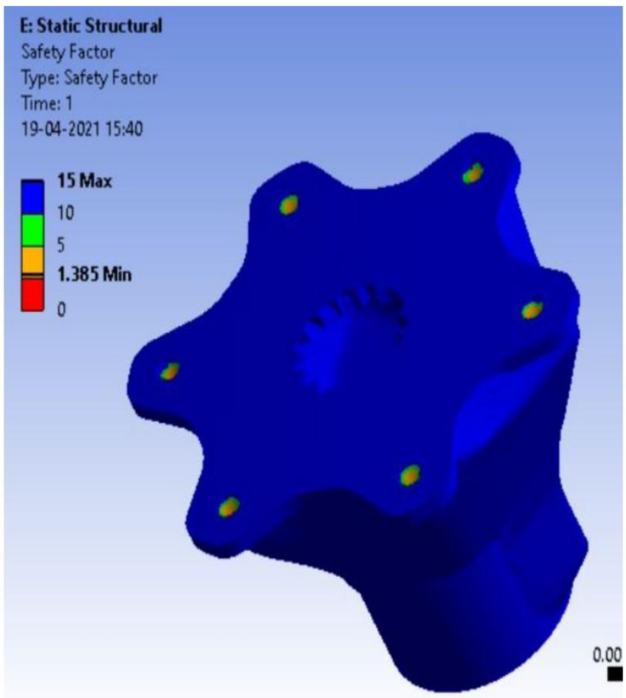
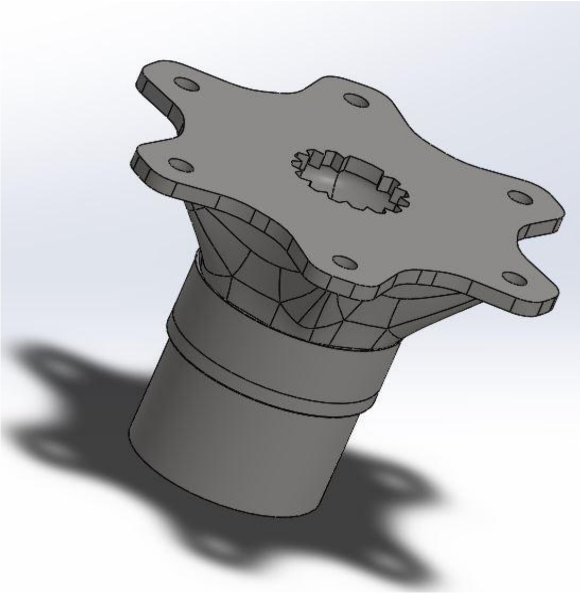


Figure: - Factor Of Safety

3. Steering Hub (3rd Iteration)



ification:

Volume = 71877.17 mm3

Mass = 532 grams

Analysis Of Steering Hub

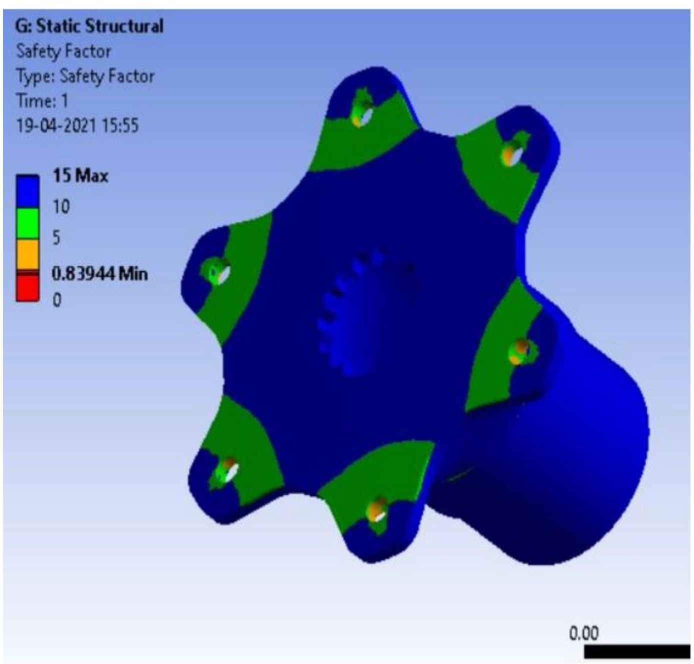


Figure: - Factor Of Safety

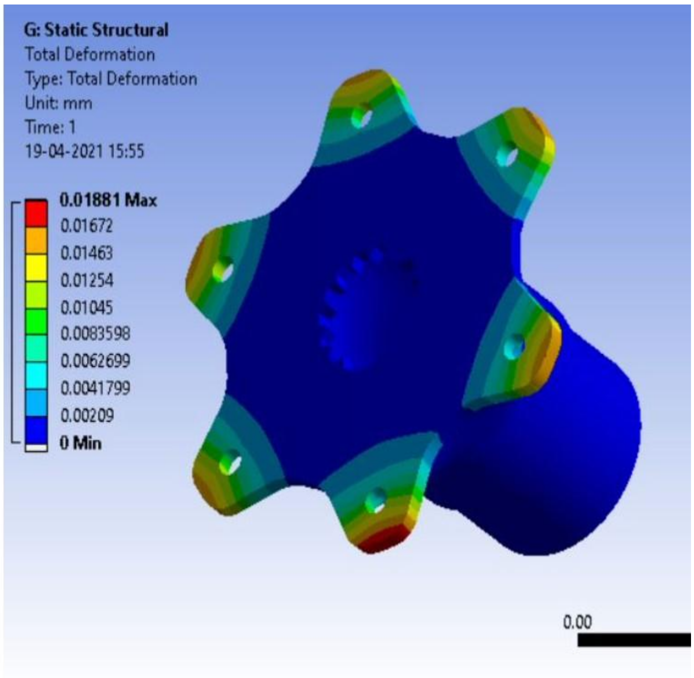


Figure: - Deformation

8. Conclusion

- In this paper we have discussed the calculation of some braking parameters which effect the performance of our vehicle, and we use AL-7075 T6 for disc brake. We go with results obtain in our simulation on ANSYS Workbench. From the set of variables, the best results are found at deformation is 0.014503 mm, factor of safety is 1.89 and temperature at 152.21 C on 4 AL- 7075 T6 with 3.5 mm thickness.

- In the case of the brake pedal, the initial weight of the component was 296 grams, the best iteration to obtain the highest factor of safety was iteration 1 with a factor of safety of 2.62. The weight reduction was 58.78% from its original weightage.
- In case of the steering wheel, the initial weight of the component was 2139.31 grams, the best iteration has a factor of safety of 7.62. The weight reduction was 59.24% from its original weightage.
- In case of the Steering hub, the initial weight of the component was 1432grams , the best iteration has a factor of safety of 1.838 (1st iteration). The weight reduction was 89.8% from its original weightage.

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