Design and Analysis of suspension system components

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ABSTRACT

Normally in automobile Mac-pherson strut type suspension system is used. In this the spring and damper system is attached directly to the knuckle's upper part via strut rod. The other end of the suspension must be connected to chassis. So, the overall height of the assembly increases. This increases the centre of gravity of car thus decreasing in performance. Pushrod and pull rod suspension systems are used in F! cars and High-performance Sports car, where centre of gravity plays an important role. This type of suspension system also reduces the unsprung mass of the vehicle. The unsprung to sprung mass ratio must be small. Polar moment of inertia of the vehicle should be small i.e. the mass should be concentrated as near to the centre of gravity as possible. The suspension system is designed by first quarter car model, then half car model and then full car model consisting of all the four wheels. Pull rod system is incorporated in front and Pushrod system at rear. Components are designed for both the static and dynamic conditions considering fatigue life also.

Keyword: - *Unsprung mass, Mac-pherson, Push rod, Pull rod, Knuckle etc.*

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1. Introduction:

Suspension is one of the most important system of automobile car which corresponds to the vehicle dynamics of car. Suspension is system comprises of components like wheel, linkages, springs, dampers, providing stability, comfortability, and preventing the vehicle and its components from the shocks and irregularities of road. But in case of formula student prototype car it is the primary goal of the suspension is to keep the wheel in contact with the road because all the forces from ground acts on the contact patch of the tires. The front and rear suspension of car may be different.

Vehicle dynamics of the car is considered from two perspectives
Ride - A car's ability to smooth out a bumpy road
Handling - A car's ability to safely accelerate, brake and corner.
These two characteristics can be further described in three important principles - road isolation, road holding and cornering.
Road Isolation- The vehicle's ability to absorb or isolate road shock from the passenger compartment
Road Holding-The degree to which a car maintains contact with the road surface in various types of directional changes and in a straight line.
Cornering- The ability of a vehicle to travel a curved path.

1.1 Objective-

1. Weight Reduction: lower the ratio of unsprung mass to the sprung mass.
2. Packaging: Packaging refers to the arrangement of all the components in proper manner.
3. Stability: Stability refers to keep the wheel of the vehicle in contact with the road in any dynamic condition.

1.2 Methodology-

1. Chassis setup
2. Selection of geometry push rod or pull rod according to space available and application
3. Selection of damper
4. Selection of parameters
5. Setup design according to results of MBD
6. Design and analysis of suspension parts.

2. Basic Parameters

2.1 Mass:
Weight of each component is taken from all over the departments and the estimated mass of the vehicle is calculated as 200 kg. Moreover, the mass of our car was 195 kg, so we assume our mass to be 195 kg without driver and 260 kg with driver (65 kg driver).
2.2 Wheelbase:
Wheelbase of the vehicle is taken as 1550 mm considering fsae rule and packaging problem and other load transfer effects.
2.3 Wheel track:
Considering the packaging problem and load transfer effects the front track width is kept wider than the rear causing maximum load transfer on the front outside tires while cornering causing a vehicle to overseer. Considering the fsae guideline the values are kept in the proper ratio.
2.4 Weight Percentage:
From the previous car data, it is assumed that the weight percentage of the car at the front to the rear is 48 to 52 %.
CG height: from the previous car data we had found that CG of that car was found to be at 210 mm from the ground. These year team has decided to lower the center of gravity. The vehicle is assumed to be at the 210mm
According to the weight percentage team has also calculated the longitudinal location of CG from the front axle and the rear axle respectively. Calculated values are as follows:

Table 1- CG Location

X (from front axle)	Y (from rear axle)	Z (from ground)
806 mm	744 mm	210 mm

2.5 Ground Clearance:
These year team has decided to keep the ground clearance of 40mm
2.6 Suspension Travel:
Assumed wheel travel of the suspension is assumed to be 1” jounce and 1” rebound.

3. G Forces-

A physical force equivalent to one unit of gravity that is multiplied during rapid changes of direction or velocity. Drivers experience severe *g*-forces as they corner, accelerate and brake.
For further designing we have to first assume the g forces that will be experienced by the vehicle which are as follows:
3.1 Acceleration:
Referring to the testing data of previous car, our vehicle completed the 75m acceleration patch in 6.38sec.by using the second kinematical equation we had calculated that maximum acceleration experienced by our car was to be 0.4 g. So, as we are using same engine and approximately same mass of the vehicle we do assume our longitudinal Tractive acceleration to be **0.4g.**
3.2 Braking:
Referring to the previous car data, we obtained our braking deacceleration to be **2.0 g.**
3.3 Cornering:
Referring to the testing data of skid pad event our car experienced lateral acceleration of 1.35 g in skid pad. Considering these data and rollover condition, our lateral g force to be **1.9 g**

4. Wheel alignment:

4.1 KPI: Kingpin inclination is the angle between the steering axis and the vertical line from the ground when seen from the front view. Generally, the value of KPI is in the range of 5-11 degrees, so team has decided to keep the KPI to be 7 degrees. As large KPI also increase the steering effort of the vehicle.

4.2 Caster: Caster inclination is the angle between the steering axis and the vertical line from the ground when seen from the side view. Generally, in case of automobiles all the vehicle prefers the positive caster as it provides straight line stability. Team kept caster of 5 degrees on the steering axis.

4.3 Camber and toe:

Camber is the inclination between vertical line passing through the center of the wheel with ground vertical.

When a pair of wheels is set so that their leading edges are pointed slightly towards each other, the wheel pair is said to have toe-in. If the leading edges point away from each other, the pair is said to have toe-out.

5.Basic Geometries:

5.1 Instantaneous center- instantaneous center is the instantaneous point about which the whole vehicle rotates. Instantaneous center is not fixed it always changes. When wheel of the vehicle goes into the bump or rebound it follows the arc.in case of quarter car of model we found the instantaneous center of rotation.

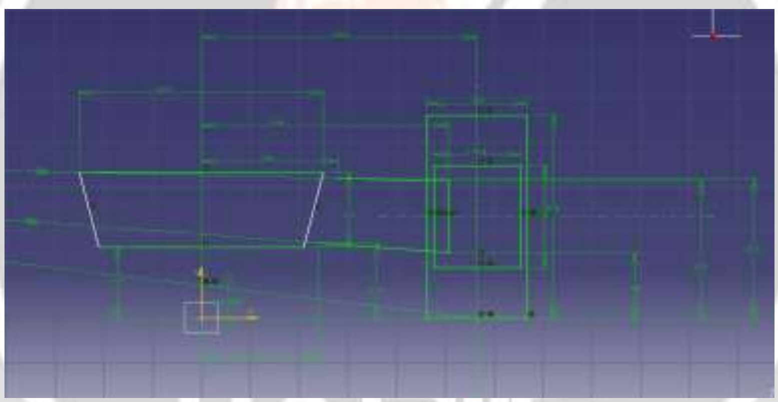

Fig.1 Rear roll center

In half car model we found the front and rear roll center respectively on Catia software which were found to be at 54mm and 74 from the ground respectively.

6.Front Suspension-

The vehicle is equipped with pull rod double wishbone independent system with A shaped wishbones consists of M5 spherical ball joints to joints wheels with chassis and M5 spherical plain bearing in upright. Wishbones are made up of steel 1018 material of 12*6.8mm and pull rod connected to the upper wishbone and other end connected to the pneumatic dampers which is connected to the chassis.

Why pull rod suspension?

The reaction forces originating due to contact of tire and road which acts on the contact patch of tire and has to be damped and transmitted into the frame of the vehicle needs to distribute in the chassis via triangulation. Therefore, taking these considerations in mind we decide to create note inside the chassis and moreover it will also bring CG down. Pull rod suspension also reduce the length of pull rod which removes its chances of buckling and moreover reduce the weight.

Front pull rod suspension consists of following components-

1. Wishbones
2. Pull rod
3. Rocker arm
4. Dampers

Fig. 2 Suspension Mounting

6.1 Installation Ratio:
It is the ratio of lengths of shock/pull rod/push rod mounting points to the total length of wishbone in the front view. It reduces the forces applying on suspension components and chassis coming through tires. These year we decide to keep the installation ratio as 0.9 which was 0.7 in the last year vehicle. These leads to reduce the dimension of wishbones resulting in less chances of bending of wishbones and more optimized components.

6.2 Motion Ratio:
It is the ratio of spring displacement to the wheel displacement from its static position. It is very important parameter while designing the suspension system. It is decided by keeping in mind the following parameters-Wheel travel, Shocks compression, Angle of inclination of shocks.
These year we have set motion ratio equal to 1 which was 0.8 in the last year vehicle which will reduce the forces coming in wheel assembly components. These leads to reduce the weight of wheel assembly components and more optimized components.

7.CAE Results-

7.1 Front knuckle- Material used: aluminium 6061

Table 2-Front Knuckle

Weight force	**Lateral force**	**Braking force**	**Braking moment**	**Steering moment**	**Wheel offset moment**
830	4500	2000	455000	18311	66400

Stress generated	**Displacement**	**FOS**
99	0.144	2.76

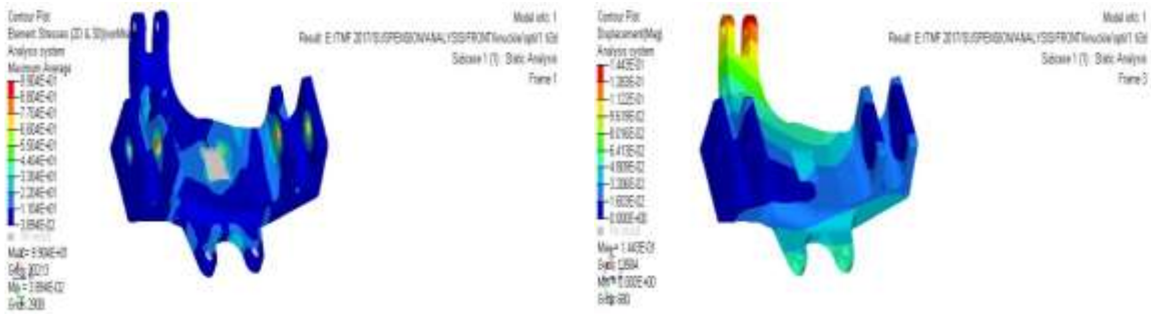

Fig. 3 Element Stresses and Displacement in front knuckle

7.2 Rear knuckle- Material used: aluminium 6061

Table 3-Rear Knuckle

weight force	Lateral force	Braking force	Braking moment	Moment due to control arm	Wheel offset Moment
790	4500	1600	210000	18311	27650

Stress generated	Displacement	FOS
40.02	0.0032	6.9

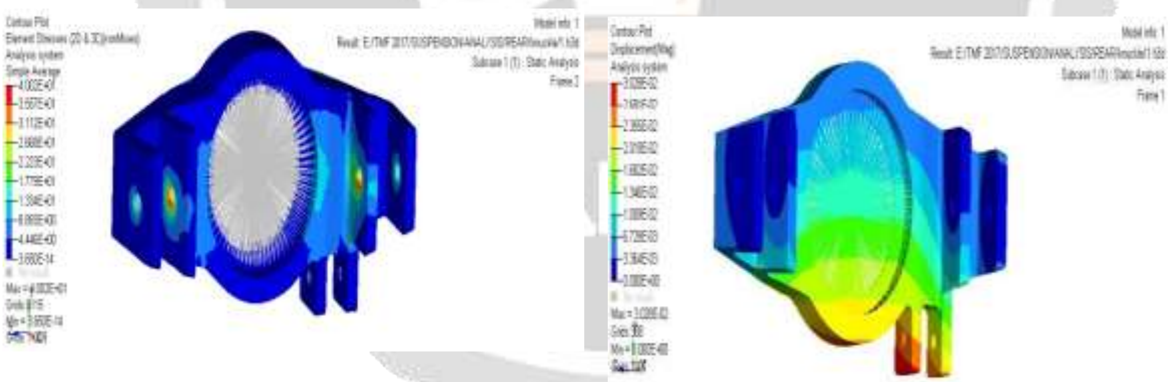

Fig. 4 Element Stresses and Displacement in rear knuckle

7.3 Front Hub- Material used: aluminium 6061

Table 4-Front Hub

weight	Lateral force	Braking force	Stress generated	Displacement	FOS
830	4500	2000	83	0.003	3.32

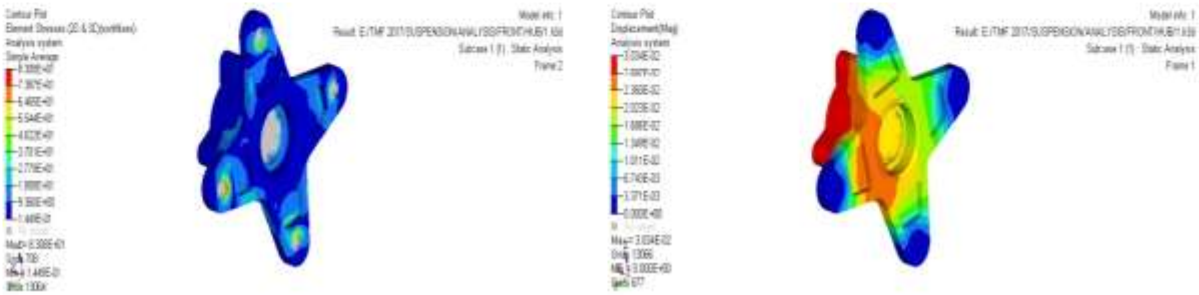

Fig.5 Stresses and Displacement in Front Hub

7.4Front A arms:
Material: steel 1018

Table 5- Front A Arms

Spring force	Lateral force	Braking force	Stress generated	displacement	FOS
527.66	566	743(2.4g/8)	112.2	0.92	3.37

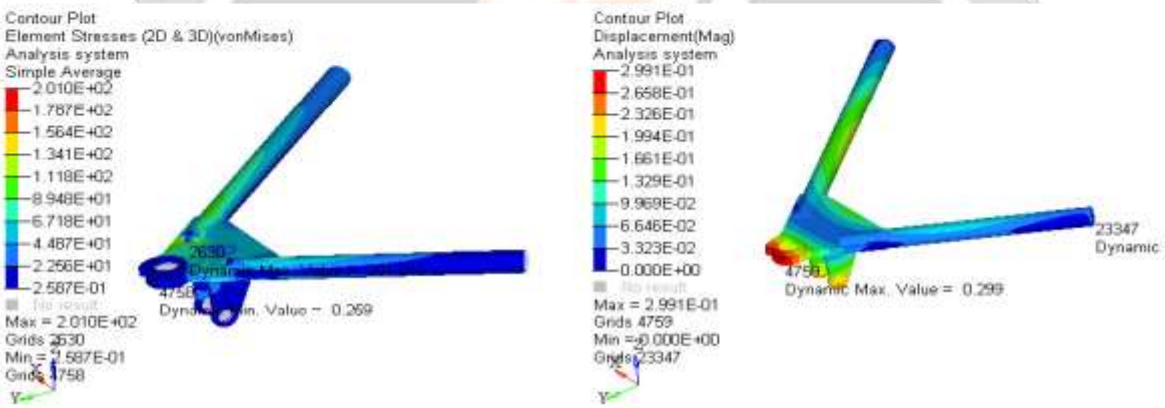

Fig. 6 Element Stresses and Displacement in front A arms

7.5 Front Bell Crank: Material: steel C45

Table 6- Front Bell Crank

Anti-roll bar	Spring Force	Force due to A- arms	Stress generated	Displacement	FOS
250 N	719.3 N	719.3 N	229.3 MPa	0.4296 mm	1.43

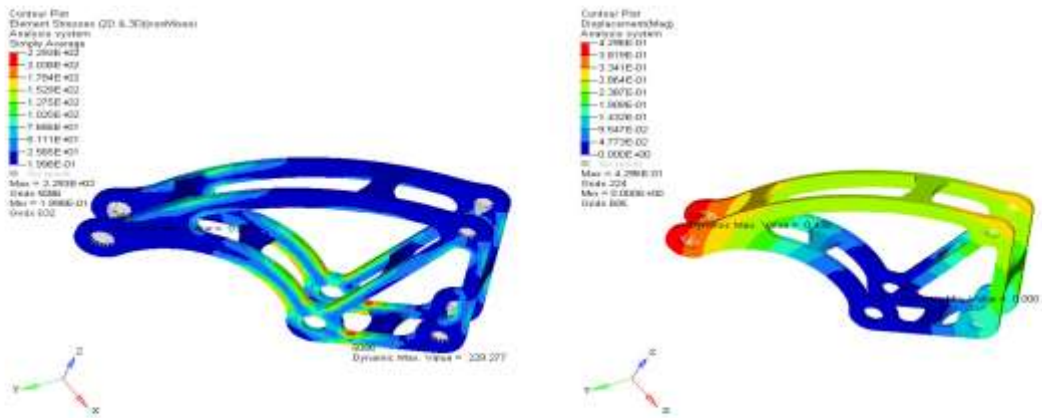

Fig. 7 Element Stresses and Displacement in Front Bell Crank

7.6Rear Bell Crank: Material: steel C45

Table 7- Rear Bell Crank

Spring Force	**Force due to A-arms**	**Stress generated**	**Displacement**	**FOS**
642.9 N	642.9 N	529.7 MPa	1.148 mm	1.1

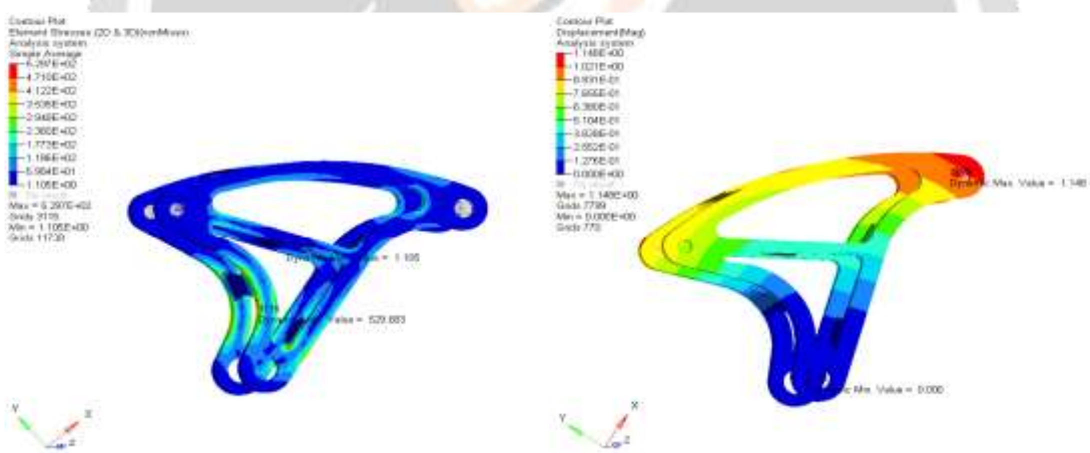

Fig. 8 Element Stresses and Displacement in Rear Bell Crank

8. CAD PARTS-

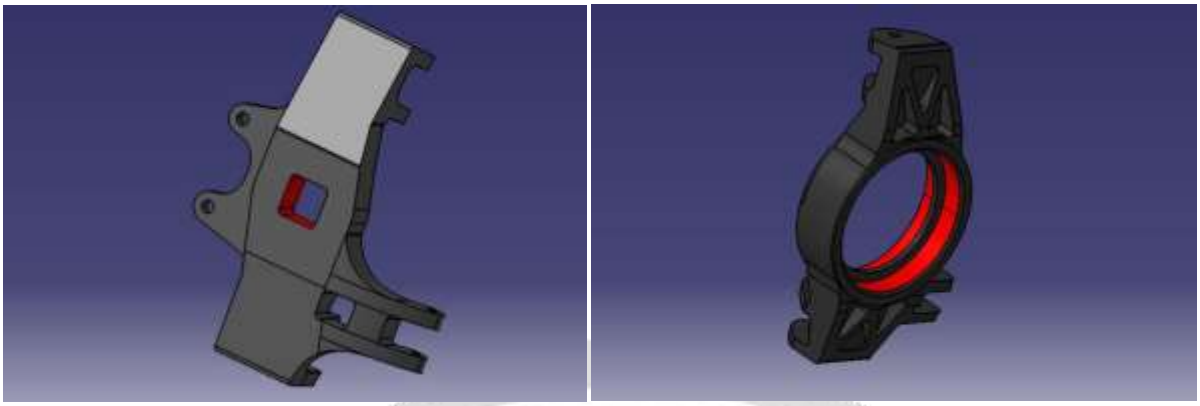

Fig. 9 Front and Rear Knuckle

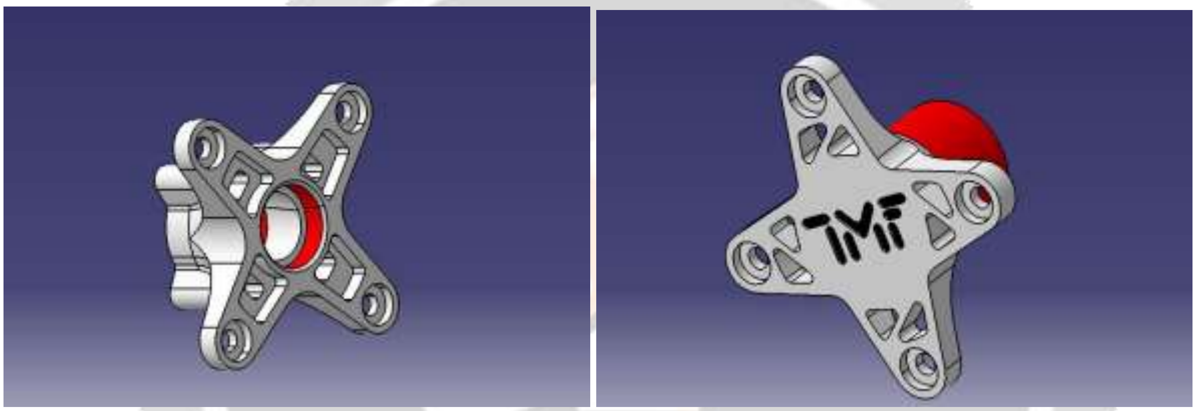

Fig. 10 Front and Rear Hub

9.Conclusion -

The design of suspension geometry is done using Catia and MBD software's while the design of component is done using Catia and Hypermesh.

10.Reference -

[1]. Race Car Vehicle Dynamics by William F. Milliken
[2]. T. Gillespie, Fundamentals of Vehicle Dynamics