STEERING SYSTEM CALCULATION AND DESIGN OF FSAE CAR

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ABSTRACT

In This Paper We are going to discuss steering system calculation and basic level of designing. We will see how to start from scratch and calculate a fully functional steering mechanism by taking all the parameters into consideration. Basically we will see the difference between software and analytical methods and conclude the results obtained from both the methods. We are using Solidworks for software methodology, and all the formulae of analytical methods are discussed later in this paper.

Keywords: Steering Mechanism, Solidworks, Analytical, Calculation, FSAE Car.

I.   INTRODUCTION

We are a formula student team(under SAE INDIA), and we fabricate Student formula race car. SAE stands for society of automotive engineers which holds SAE-SUPRA Competition at BIC every year. Talking about the steering system, it is one of the most important departments of not only Vehicle dynamics but also for the whole car. Steering mechanism depends upon a number of criteria such as trackwidth, wheelbase , lock angles , suspension etc.(In this paper our scope is restricted to steering part only). The main intention of the steering should be that it should take the desired turn as per drivers input with predefined turning radius of the car. Trackwidth, wheelbase and lock angles are the three most parameters to start with and then comes selection of steering type.

II.   METHODOLOGY

Selection of Steering Mechanism :

There are 2 main types of steering mechanism widely used named as-

1. Ackermann geometry

2. Anti-Ackermann geometry

In Ackermann steering geometry the outer lock angle is greater than the inner wheel and the outer wheel covers a larger distance and vice-versa for Anti-Ackermann. Both the geometries have their own importance but Ackermann geometry is widely used due to various factors such as..

● Easy to design

● Easy to make changes

● Easy to manufacture

● Reduces friction and steering effort as compared to anti-ackerman

● Better stability

Due to such reasons Ackermann steering is selected . FASE has their own rules and we have to follow them while designing and confirming all other parameters. We are going to use software(solidworks) and analytical both the methods...so let's get started with the software method first
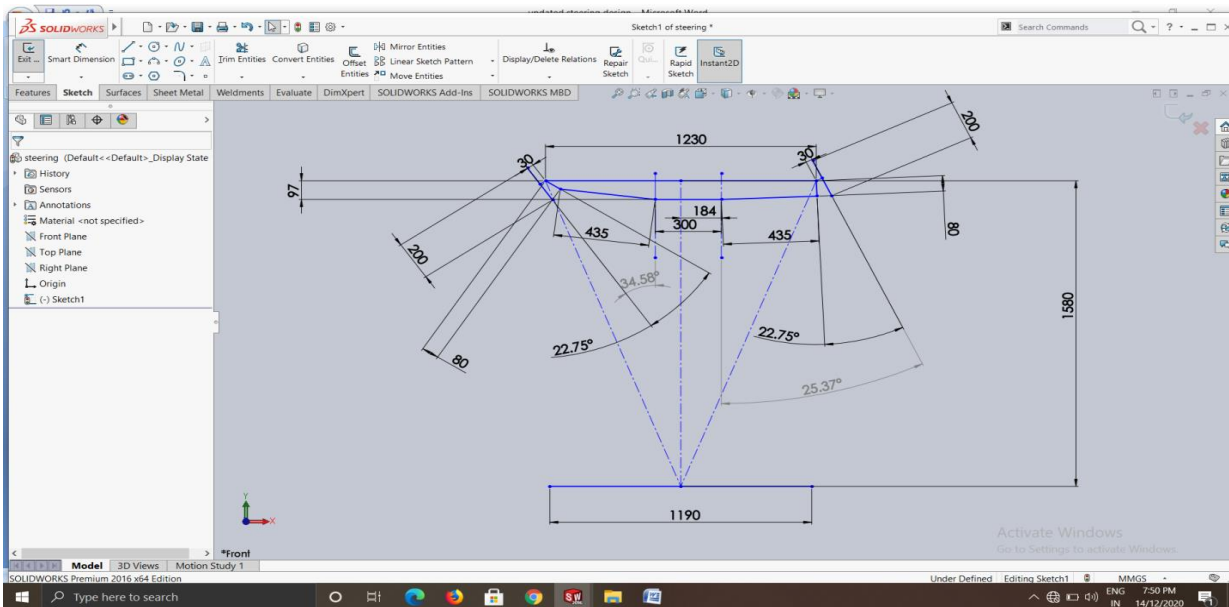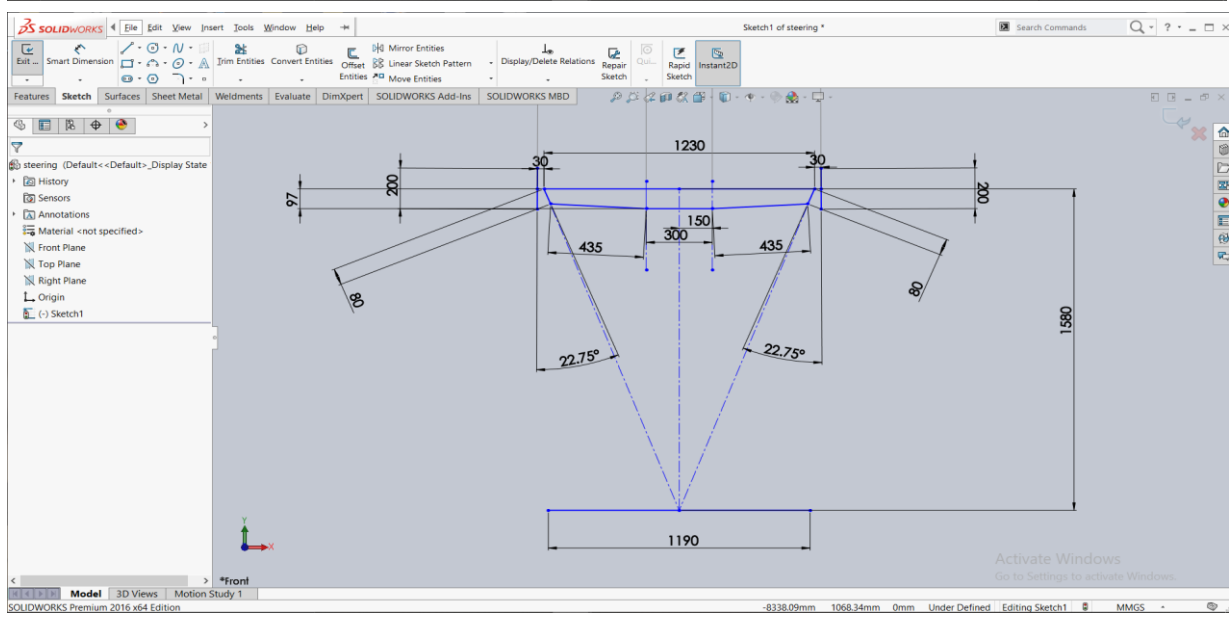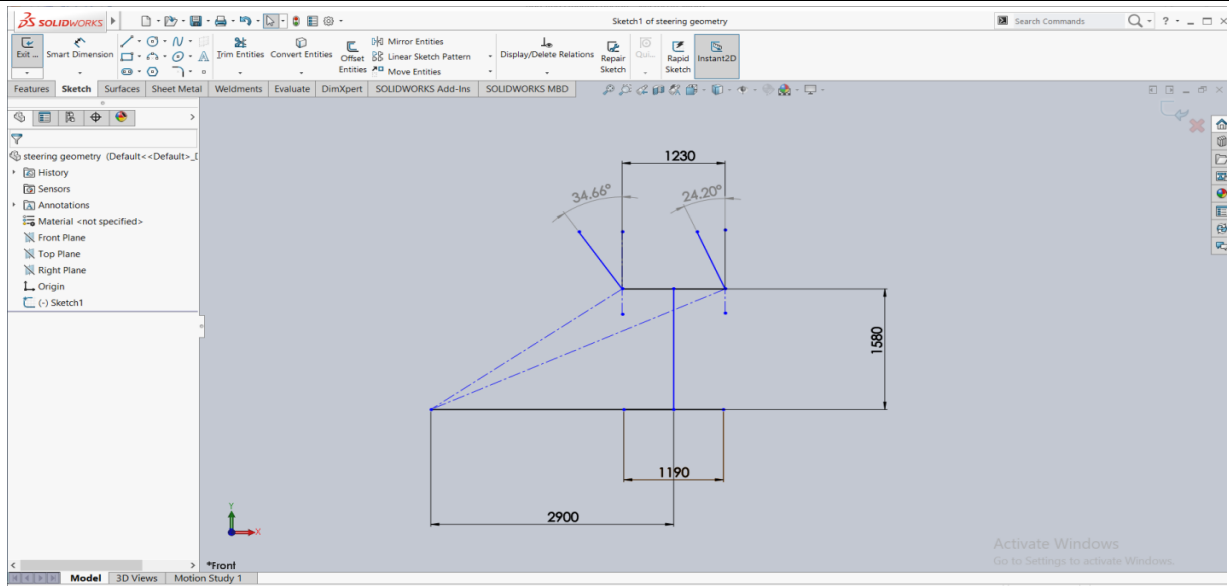
As you can see from the pictures above , first we finalized the lock angles, turning radius, wheelbase, trackwidth and then we started with Rack and Pinion designing to meet our basic requirements. We first took trackwidth and wheelbase allowed as per rule book and then did iterations on that to match our requirements. All these things are interlinked with each other, change in any Parameters affect another. So after analyzing everything which suits our design of car and also feasible for software calculation, we came to final outcomes.

Note – There are numbers of iterations done before coming to these final values and then we started with rack and pinion designing as per our need. Lateral and longitudinal weight transfers are also considered but they majorly come under Vehicle dynamics that's why we are not going to discuss it here.

There are numerous factors which we have to look upon like C-factor , no. of teeths for rack and pinion , steering arm length ,steering points , steering column and also steering wheel should be placed such a way that it should be comfortable for driver to get in and out of the car easily due to space constraints in cockpit. Driver should not fatigue and our Mechanism should match our basic requirement with as much as less effort applied by the driver.

For Software Method we finalized following parameters :

1. Lock angles :**I 34.66/o 24.20** (actual)
          I 34.58/o 25.37 (solid works)

Total difference from actual **0.08/1.17**.

2. Wheel base : **1580mm**

Track width (front): **1230mm**

Track width (rear): **1190mm**

3. Tie rods length : **435mm**

4. Steering Arms Length : **80mm**

5. Distance between front axle and rack : **97mm**

6. Desired rack travel : **34mm**

7. Steering ratio : **5.20:1**

8. Minimum turning radius : **2900mm**

9. Ackerman angle : **22.75**

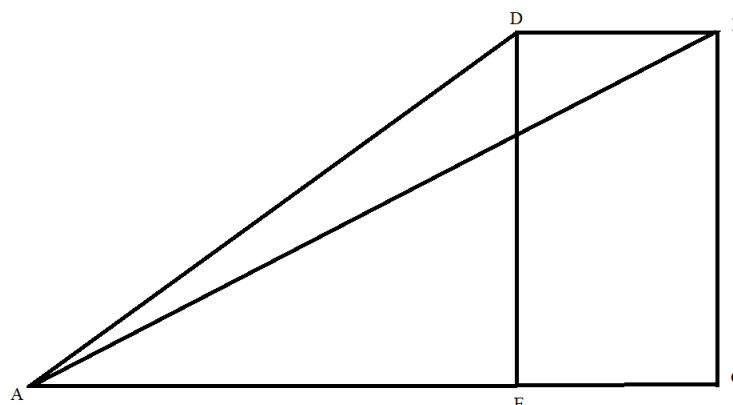We will cross check this values with our analytical calculations

Wheel Base= 1580mm (1.58m)

Steering Ratio=5:1

Average Steer Rate=36

Track Width Front Axle Length(BD)=1230mm
          Rear Axle Length(EC)=1190mm

TURN RADIUS

Turn Radius = 2900mm

OUTER ANGLE

tan φ=Wheelbase/(Turn radius + half rear axle length)

   =$\tan^{-1}$(1580)/(2900+595)

   =24.32

AB=$\sqrt{}$ (AC^2+ BC^2)

   =$\sqrt{}$ (3495^2+1580^2)

   = 3835.55

INNER ANGLE

tan Θ=Wheelbase/(Turn radius-half rear axle length)

   =$\tan^{-1}$(1580)/(2900-595)

   =34.42

AD=$\sqrt{}$ (AE^2+ DE^2)

   = $\sqrt{}$ (2305^2+1580^2)

   =2794.53

ACKERMANN ANGLE

Ackerman Angle= 22.75 (By trial and error basis on SolidWorks)

RACK and PINION

Rack Length=300mm

Tie Rod= 435mm

Distance between Rack and Front Axle=97mm

Steering Armlength= 80mm

Rack Travel= 34mm

The above values are obtained by Trial and error on SolidWorks

Material Properties – Al 707s t6

1) Hardness

a. BHN 150

b. Knoop 191

c. Rockwell 53.5

2) Ultimate Tensile Stress (UTS) = 541 Mpa

3) Yield Strength (YS) = 468 Mpa

4) Modulus of Elasticity = 71.7 Gpa

5) Poission's Ratio = 0.33

6) Melting Point = 477

Endurance Limit=σ_b=(UTS/3)=541/3= 180.33

Assumptions Made:

1. Full Load acts at the tip of a tooth.

2. The effect of radial force is neglected.

3. Stress concentration is neglected.

4. Frictional force due to sliding of the tooth is neglected.

● As per BIS standards a 20^0 full depth tooth profile is selected because of its property of generating less interference and reduced risk of undercutting.

Let's assume,

z_1 = 20 teeth

Standard module m= 1.5

PCD= d_1= m*z_1

=1.5*20

=30mm

Calculations:

σ_b= 180.33

1) Lewis Form Factor

Y_p=0.484-(2.87/Z_p)

=0.484-(2.87/20)

=0.3405

2) Beam Strength

$P_b = \sigma_{bp}$*b*m*Y_p

=180.33*10*m*m*0.3405

=614.024 m^2N

3) Wear Strength

P_w = b.Q.d_p.k

=10m*1.2*20m*0.36

=86.4 m^2N

Consider P_{eff}=760.966N = 800 N

P_w=N_f*P_{eff}

m=4

PCD =80mm

Pitch = π*m =π*4=12.56mm

Pressure Angle=20^0

Addendum=4mm

Dedendum=5mm

Clearance= 1mm

Working Depth= 8mm

Whole Depth=9mm

Tooth Thickness=6.28mm

Z_p = 20 teeths

$Z_g = \frac{2*Rack\ Travel}{Pitch}$

=2*34/12.56

=5.42

=6 teeths

STEERING EFFORT

Torque on Pinion= Rad of pinion*weight on front wheel

= 40*131.3396875

=5253.5875

Force applied on steering wheel:

Static coefficient of friction = 0.7

Dynamic coefficient of friction = 0.4

Static = (torque on pinion * coefficient of friction$_{static}$)/steering wheel diameter

=(5253.5875*0.7)/200

=18.39

Dynamic = (torque on pinion * coefficient of friction$_{dynamic}$)/steering wheel diameter
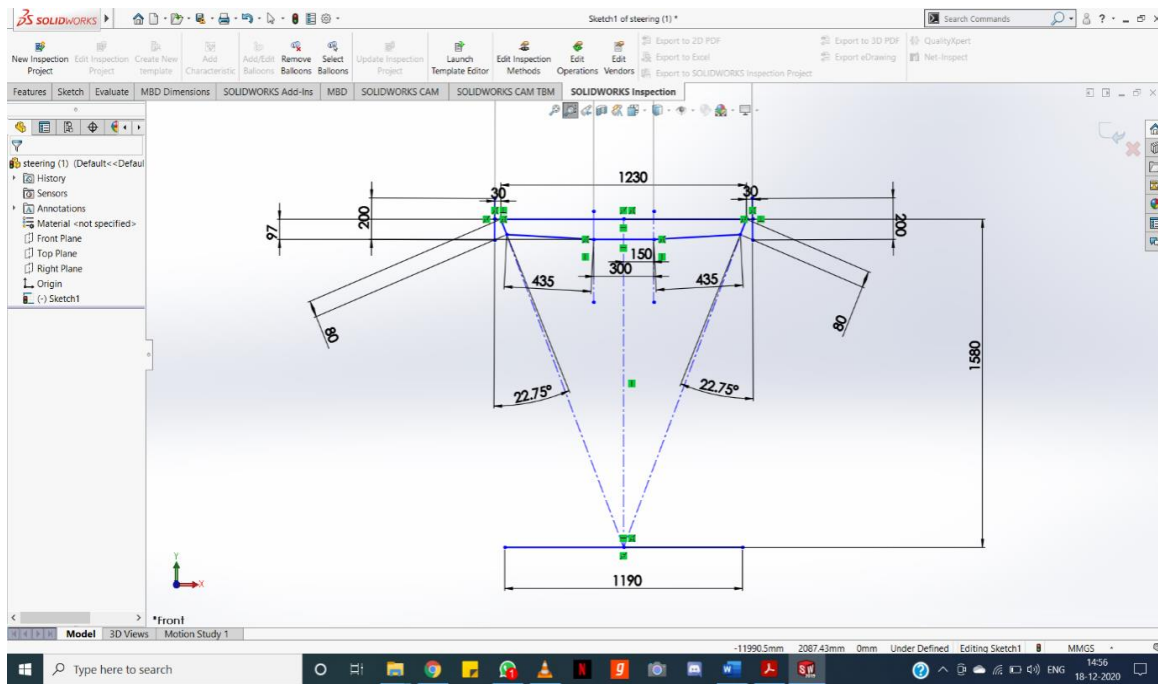
$$=(5253.5875*0.4)/200$$

$$=10.5$$

C factor=(rack travel/angle turned by steering wheel)*360

$$=(34/24.32)*360$$

$$=503.29$$

III.   MODELS AND DRAWING

FINAL STEERING GEOMETRY :

IV.   RESULTS AND DISCUSSION

From calculations from both Software Method and Analytical Method, We can see difference of 0.08 for inner and 1.17 for outer Turning radius

Here are some extra Calculations we did to finalize our parameters :

Sr no.	Max steering Inside/outside	Difference I/O	Ratio	Rack Travel(mm)	Dis. Between front trackwidth and rack(mm)	Steer arm length (mm)	Tie rods length (mm)
1.	24.36/19.09	11.52/5.88		40	173.25	125.88	458.44
2.	33.76/23.92	2.12/1.05		50	173.25	125.88	458.44
3.	22.64/19.63	13.24/5.34		40	160	125.88	458.44
4.	30.94/24.18	4.94/0.79		50	160	125.88	458.44
5.	20.87/20.11	15.01/4.86		40	140	125.88	458.44
6.	28.22/24.67	7.66/0.3		50	140	125.88	458.44
7.	27.48/19.81	8.4/5.17		40	140	115	458.44
8.	38.30/24.78	-2.42/0.18		50	140	115	458.44
9.	35.69/23.79	0.19/1.18		48	140	115	458.44

10.	35.36/25.07	0.52/-0.1		50	125	115	458.44
11.	35.30/23.45	0.58/1.52		36	173.25	92.50	458.44
12.	35.80/27.07	0.08/-2.1		39	80	84	470
13.	34.93/23.36	0.95/1.61		39	150	100	471
14.	**34.58/25.37**	**0.08/1.17**	**5.20 : 1**	**34**	**97**	**80**	**435**

V.   CONCLUSION

After many Iterations ,Hence we conclude that analytical and software methods both give same result with minimal amount of difference which is acceptable. We need to changes our values accordingly which is best suitable for our car in actual Conditions and not just on Software.

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