Optimization of Suspension Parameters using LOTUS Shark Suspension Analyser

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***Abstract*— Suspension and steering systems are considered to be one of the major systems of the vehicle dynamics. The suspension helps in absorbing the various forces acting on car for eg. Bumps, droop, roll, pitch, bounce etc. and provides a comfortable ride to the driver. The main aim of this paper is to optimize the suspension and steering system for a formula SAE vehicle. The achieving of good riding condition of the car involves compromise between different static as well as dynamic factors and thus we plan to build a good suspension geometry by taking iterations of combination of various factors and optimizing it by using LOTUS Shark suspension analyzer. Kin pin inclination (KPI) and Castor angle both were optimized to 4 degrees. Whereas Camber angle for front was optimized to negation 2 degrees and for rear it was optimized to negative 1 degree. Using LOTUS Shark suspension analyzer we were expecting the variation in above angle to be within plus or minus 1 degree.**

Keywords*— Camber, Castor, Kin pin inclination (KPI), Suspension, Steering, Geometry, Formula Society of Automotive Engineers (FSAE), Ackermann, LOTUS Shark.

I. INTRODUCTION

FSAE race car is a single driver system which is designed to race on track having multiple number of turns along with testing its acceleration. The basic aim of FSAE race car is to achieve a better ride and stability at good speed across the track. The suspension and steering system have to undergo different driving conditions, thus there are many static as well as dynamic factors which influence the behavior of a car during these conditions. Suspension geometry depends on many parameter out of which 3 parameters have been discussed in this paper namely:

1. Camber change due to bump.
2. Camber change due to roll.
3. Camber change due to steering.
4. KPI change due to bump.

II. OBJECTIVE

- To minimize camber gain due to bump.
- To minimize camber gain due to roll.
- To minimize camber gain due to steering.
- To minimize KPI gain due to bump.
- To better ride stability at all condition.

III. BASIC TERMINOLOGY

A. *Kingpin inclination:*

It is also known as “Steering axis inclination” is the angle from vertical to the steering axis of the tire between the upper and lower ball joint viewed from the front as shown in fig 1.

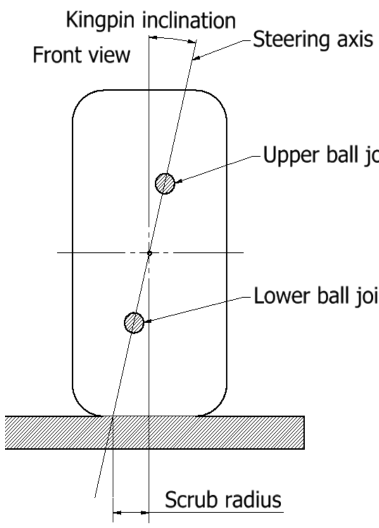

Fig 1: Kingpin inclination and Caster angles

B. *Camber Angle*

The angle of the wheel in- or outwards respective to vertical viewed from the front is called a camber angle. It is shown in fig 2.

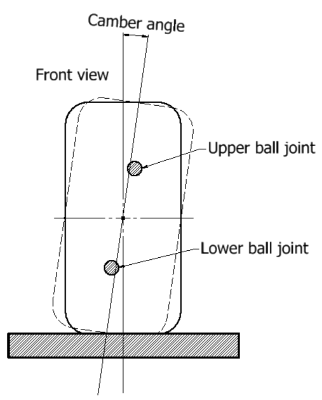

Fig 2: Camber angle

IV. METHODOLOGY

The static camber and the camber variation would play an important role in the performance of the car as well as the life cycles of the tires. Camber angle is mainly dependent on the lateral Vertical Swing Arm Length (VSAL). So, to minimize the camber change in all the 3 modes i.e. heave, roll, steering. However, a compromise needed to be made since changing the length of the VSAL would have opposite effects on camber change during roll and heave. Camber change due to steering depends purely on the KPI and the caster angle. Along with minimizing the camber change we also focused on KPI change due to wheel travel.

The suspension geometry had to be analysed using a particular software to determine the suspension parameters for best values of bump and roll steer. The software chosen was LOTUS Shark suspension analyser due to its ease of use and accurate results. The process used was to determine the 2D suspension points in Solidworks and then input them into LOTUS Shark analyser.

Table 1: General data

General Data		
Car Weight	200	Kg
Driver Weight	60	Kg
Total	260	Kg
Weight Distribution (Front)	43	%
Weight Distribution (Rear)	57	%
Front Weight	111.8	Kg
Rear Weight	148.2	Kg
CG Height	310	Mm
Lateral VSAL Front	1618.06	Mm
Lateral VSAL Rear	1286.62	Mm
KPI	4	Deg
Castor	4	Deg
Static Camber Front	-2	Deg
Static Camber Rear	-1	Deg
Track Width Front	1200	Mm
Track Width Rear	1150	Mm

Table 1 shows general data, this information was used to plot graphs for analytical data. This analytical was compared with Lotus shark result.

Table 2: Hard points for LOTUS shark (Front)

Sr. No.	Hard Points	Lotus X	Lotus Y	Lotus Z
1	Lower Wishbone front pivot point	-150	-213.8	145.8
2	Lower Wishbone rear pivot point	150	-213.8	145.8
3	Lower Wishbone outer ball joint	-5.79	-539.8	145.8
4	Upper Wishbone front pivot point	-150	-242.2	280.8
5	Upper Wishbone rear pivot point	150	-242.2	280.8
6	Upper Wishbone outer ball joint	5.79	-528.22	311.4
7	Push Rod wishbone end	4.78	-478.52	306.8
8	Push Rod rocker end	1.17	-307.63	145.59
9	Outer track ball joint	74.69	-508.85	178.5
10	Inner track ball joint	80	-208.52	178.5
11	Damper to body point	0	-272.5	416.88
12	Damper to rocker point	1.48	-318.59	201.76
13	Wheel spindle point	0	-534.17	226.44
14	Wheel centre	0	-592.02	228.46
15	Rocker axis 1st point	-19	-259.63	125.8
16	Rocker axis 2nd point	19	-259.63	125.8

Table 2 shows hard points in Cartesian co-ordinate system for front suspension geometry.

Table 3: Hard points for LOTUS shark (Rear)

Sr. No.	Hard Points	Lotus X	Lotus Y	Lotus Z
1	Lower Wishbone front pivot point	1385	-195	146.6
2	Lower Wishbone rear pivot point	1635	-195	146.6
3	Lower Wishbone outer ball joint	1569.25	-538.95	146.3
4	Upper Wishbone front pivot point	1385	-233.52	273.85
5	Upper Wishbone rear pivot point	1635	-233.52	273.85
6	Upper Wishbone outer ball joint	1580.75	-527.45	310.9
7	Push Rod wishbone end	1635	-555	300.9
8	Push Rod rocker end	1635	-290.82	458.58
9	Outer track ball joint	1635	-555	171.3
10	Inner track ball joint	1635	-202.48	171.3
11	Damper to body point	1635	-35	461.86
12	Damper to rocker point	1635	-254.58	475.51
13	Wheel spindle point	1575	-533.24	227.99
14	Wheel centre	1575	-566.01	228.57
15	Rocker axis 1st point	1654	-239.92	396.86
16	Rocker axis 2nd point	1616	-239.92	396.86

Table 3 shows hard points in Cartesian co-ordinate system for rear suspension geometry

V. PREAMBLE

The result was obtained from LOTUS Shark analyser. After the first set of points were entered into the software, a number of iterations were carried out to determine the best possible values for the suspension geometry.

VI. RESULT

A. Analytical graphs using general data of Table 1

1) Camber v/s Roll angle analytical graph

In camber v/s roll angle graph (fig 3), it has been observed a linear relation between camber and roll angle. As roll angle increased from -2 degree to 2 degree, camber is found to vary from -3.2584 degree to -0.7416 degree.

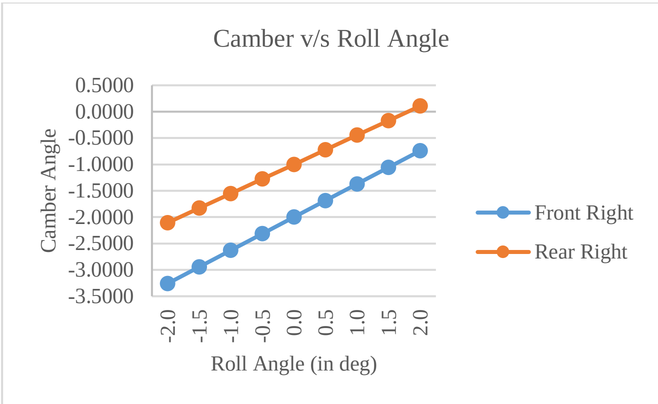

Fig 3: Camber v/s Roll angle graph

2) Camber v/s Bump analytical graph

In camber v/s bump graph (fig 4), it has been noted that as bump increased from -30mm to 30mm, camber is set up to vary from -0.9378 degree to -3.0622 degree.

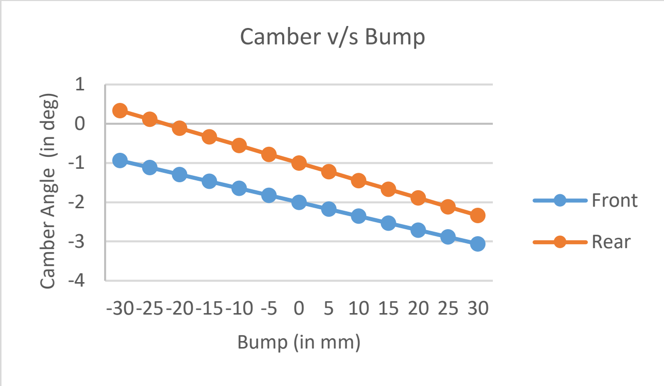

Fig 4: Camber v/s Bump graph

3) *Camber v/s Steering Angle analytical graph*

In camber v/s Steering angle graph (fig 5), the camber angle is found to differ from 0.5358 degree to -3.4641 degree as steering angle increased -30 degree to 30 degree.

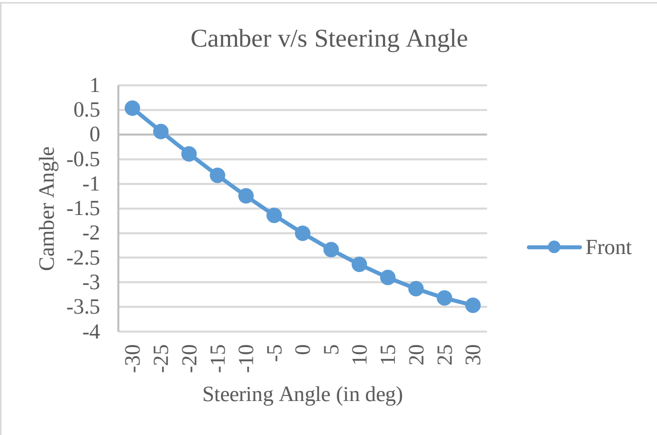

Fig 5: Camber v/s Steering Angle graph

4) *KPI v/s Bump analytical graph*

From above graph it has been noted that KPI increased as bump increases. KPI altered from 2.7162 degree to 5.2832 degree.

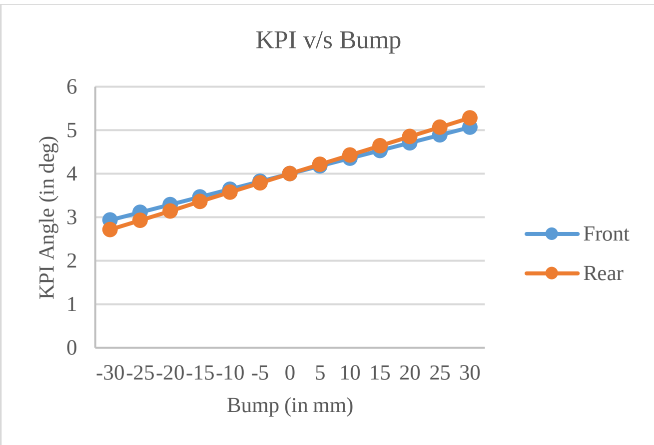

Fig 6: KPI v/s Bump graph

B. *From Lotus shark suspension analyser we got following graph*

1) *Camber v/s Roll angle graph from LOTUS*

With increase in roll angle, camber is found to alter from -3.265 degree to -0.7693 for front whereas for rear it was -2.1729 degree to 0.0799 degree.

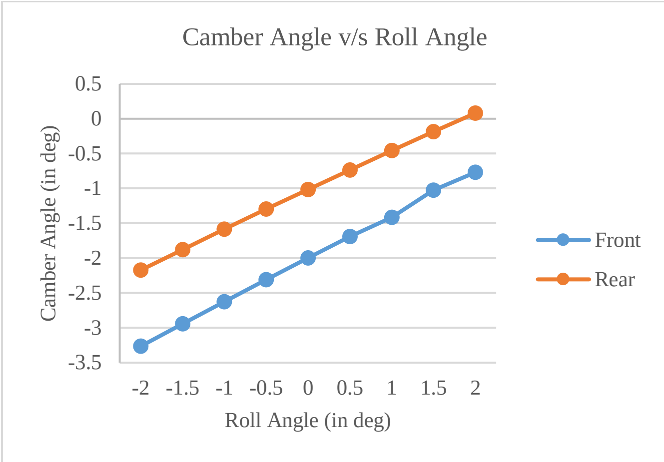

Fig 7: Camber v/s Roll angle graph from LOTUS

2) *Camber v/s Bump graph from LOTUS*

As bump increased from -30mm to 30mm, camber angle differ from -0.9596 degree to -3.0576 degree for front and from 0.2354 degree to -2.4038 degree for rear.

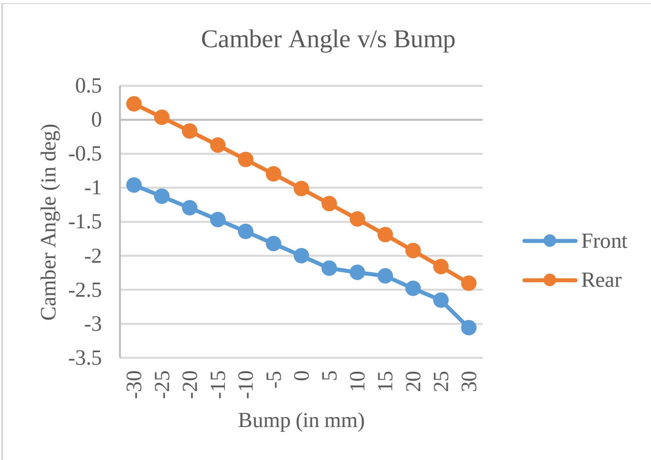

Fig 8: Camber v/s Bump graph from LOTUS

3) *Camber v/s Steering graph from LOTUS*

As steering angle increased from -30 degree to 30 degree, LOTUS gave camber change from -3.35 degree to 0.06 degree

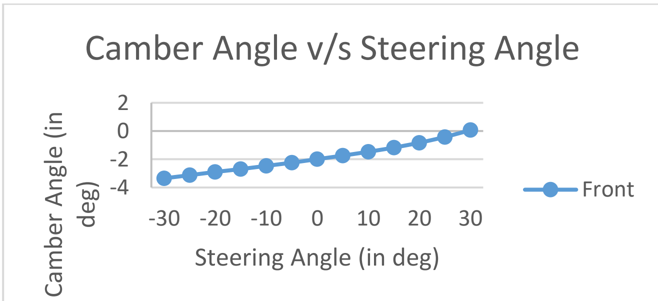

Fig 9: Camber v/s Steering graph from LOTUS

4) KPI v/s Bump graph from LOTUS

Camber altered from 2.9929 degree to 4.8666 degree in front and 2.7787 degree to 5.3511 degree in rear with increase in bump from -30mm to 30mm

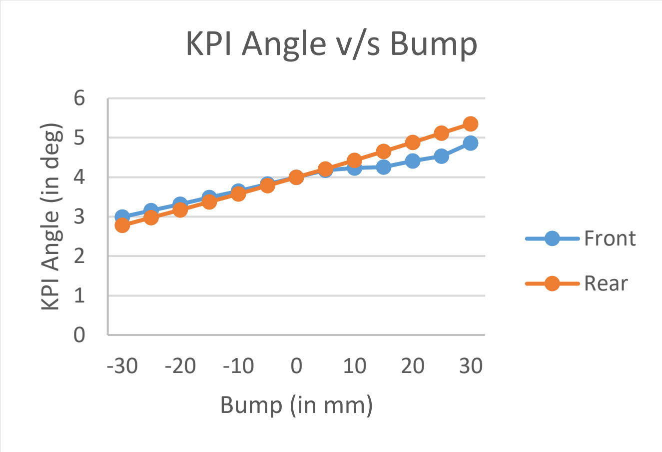

Fig 10: KPI v/s Bump graph from LOTUS

VII. DISCUSSION

After all the calculations were completed and analysis in LOTUS Shark suspension analyser was conducted the final suspension and steering assembly was designed in Solidworks. From all the above graph, we come a decision that there is no as such variation from analytical calculation and LOTUS Shark suspension analyser.

This suspension and steering system designed for the turns and forces in terms of bump generally encountered in the FSAE events was optimal to counter negative impacts of bump and roll steer. Camber and KPI change was in the range of -1 degree to +1 degree of selected value. This angle change ensures that the tyres of car are in contact with road surface throughout the duration of event.

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