

Design Optimization of a Formula Student Suspension

Prof. Viraj Indrajeet Pasare¹, Rajvaibhav Shivajirao Patil², Swapnil Subhash Bhosake³, Bilal Rafiqmohammed Bhore⁴, Indra Ramsuresh Nishad⁵

¹Asst. Professor, Department of Mechanical Engineering, D.Y. Patil College of Engineering & Technology, Kolhapur, Maharashtra, India.

^{2,3,4,5,6}Student, Department of Mechanical Engineering, D.Y. Patil College of Engineering & Technology, Kolhapur, Maharashtra, India.

Abstract - As the suspension system handles most of the dynamics of the vehicle, it is very important for a suspension designer to design the suspension in a very proper way and using proper tools to correctly predict the performance of the vehicle. As accurate prediction of the vehicle performance is not possible due to many non-linearities in the system, simulation tools make it possible to get the nearly accurate values of the intended parameters. This article shows the use of simulation tools in optimizing the suspension geometry and design using simulation tools like MSC ADAMS and MATLAB.

Key Words: Suspension Geometry, Camber, Caster, Toe, King Pin Inclination, Scrub Radius, Spring Rates, Ride, Roll, Cornering force, Slip Angle, MSC ADAMS, MATLAB.

1. INTRODUCTION

The suspension design in a vehicle is an iterative process and as far as the motorsports are concerned, it is a very critical task to maximize the tire grip by an optimizing the suspension design. Also, this requires a detailed analysis of the tire data which requires a whole understanding of the dynamics of the vehicle. Here, simulation tools like MSC ADAMS and MATLAB help us reduce hand calculations, analytical processes and time involved in designing and optimizing the suspension system.

2. TIRE DATA AND SUSPENSION GEOMETRY

The suspension geometry plays an important role in deciding the dynamics of the vehicle. The position of the roll centers, the instant centers and the lengths of the front view and side view swing arm lengths determine how the wheels behave while ride/ bump and roll conditions. These are very important criterion for optimizing the suspension geometry and stabilizing the vehicle while accelerating, braking, cornering and maneuvering.

The best way to design the suspension geometry is to start from the tires. We selected BKT 205/50/10 tires that were selected by analyzing and comparing the tire data. We used MATLAB for tire data fitting and also MSC ADAMS for using the tire model for our vehicle model.

We used Solidworks 2017 for designing our suspension geometry because it was easy to modify our drawings in it and also its add-ons help us for doing simple measurements.

It is also simple to draw and project multiple views of the same geometry.

Table -1: Vehicle Static Characteristics

Preparation of Manuscript			
Camber : Front	1.5 deg	Camber : Rear	1.5 deg
Caster : Front	4 deg	Caster : Rear	0 deg
Toe : Front	0 deg	Toe : Rear	0 deg
King Pin Inclination : Front	5.5 deg	King Pin Inclination : Rear	0 deg
Scrub Radius : Front	25mm	Scrub Radius : Rear	45mm
Track width: Front	1300mm	Track width: Rear	1245 mm

Finalizing the vehicle static characteristics is also an iterative process. First the tire data was compared and the characteristics were found out corresponding to the wheel vertical loads, longitudinal loads, lateral forces, speed, etc. The characteristics which give maximum acceleration are selected.

Tyre:	FSAE	Pressure	Camber (°)											
			0	0.5	1	1.5	2	2.5	3	3.5				
Spec :	14140S													
Size:	205/50/10	17psi	18.3	18.1	18.3	17.4	17.7	17.6	17.5	16.8				
Rim:	9.01 x 13"	19psi	19.4	20.1	19.4	19.1	18.8	19	19.1	18.6				
Project	RC1027SPC	21psi	20.4	20.5	21	20.5	20.1	20.3	20	19.7				
Tested	21-11-2013	23psi	22.1	22.1	22.1	22.1	22	22.3	21.8	21.2				

Chart -1: Spring rates of tire at various tire pressures and camber angles

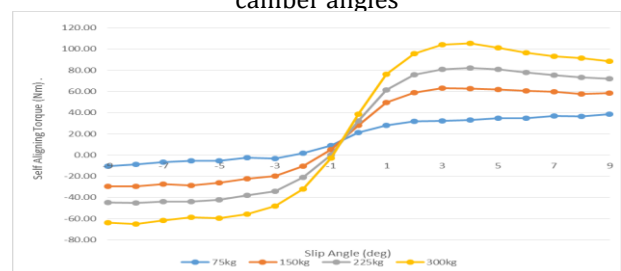


Chart -1: Self Aligning Torque vs Slip Angles at various loads

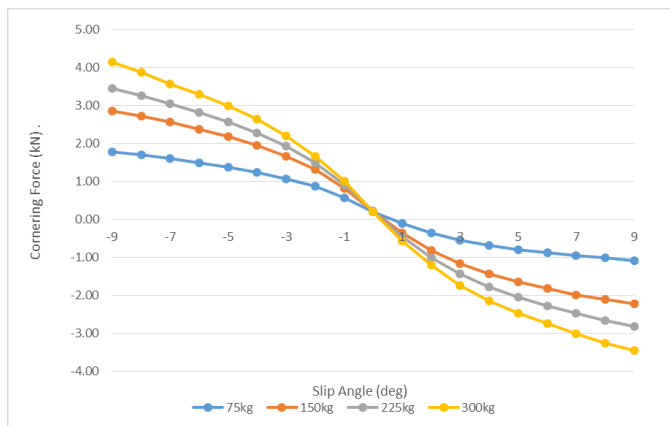


Chart -2: Cornering force vs Slip Angles at various loads

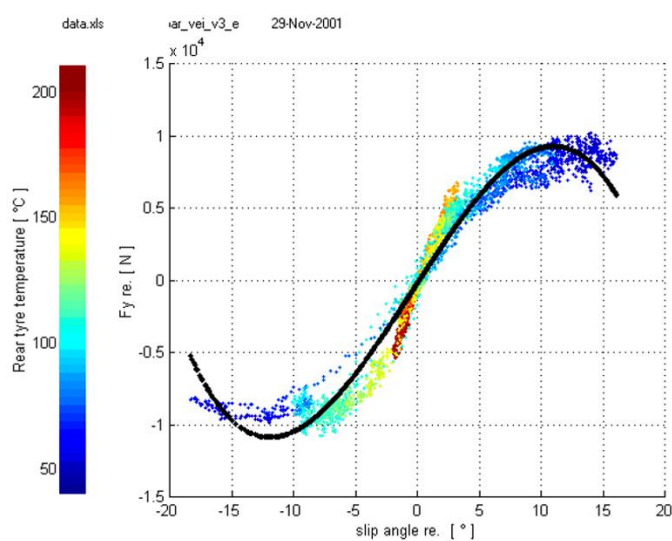


Chart -3: Fitting of tire data

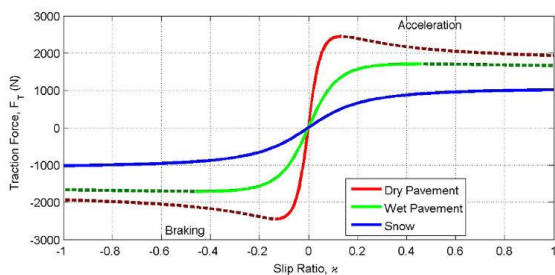


Chart -4: Tractive forces and acceleration on various surfaces

Some manufacturers give this data in various forms like charts, tables, etc. We need to compare this data and then select a suitable tire. This process is critical to analyze and compare without the help of computational tools. We used MATLAB for tire data fitting and then selected our tire.

After the tire data and the static vehicle characteristics are described, the suspension geometry in Solidworks is made. The roll characteristics are decided by the front view geometry and the ride characteristics are decided by the side

view geometry of the vehicle. Figures below show the suspension geometry for the front suspension.

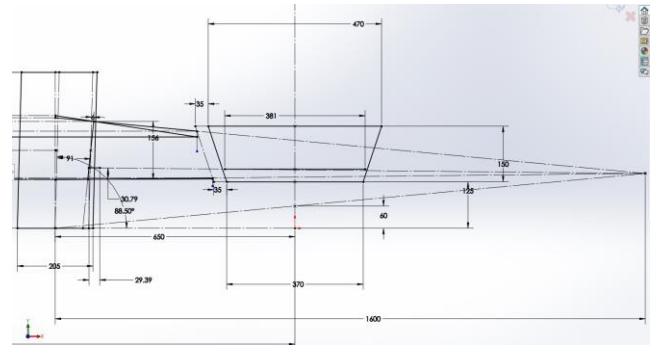


Fig -1: Front Suspension front view geometry

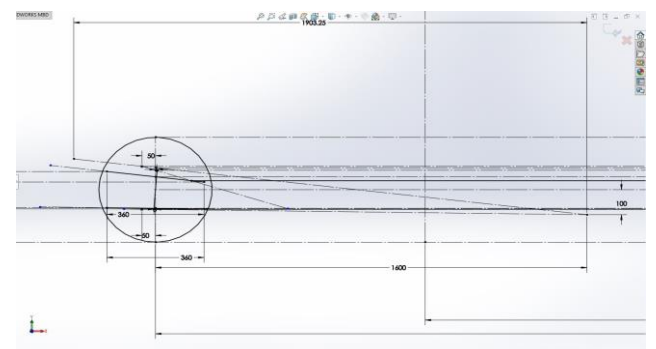


Fig -2: Front Suspension side view geometry

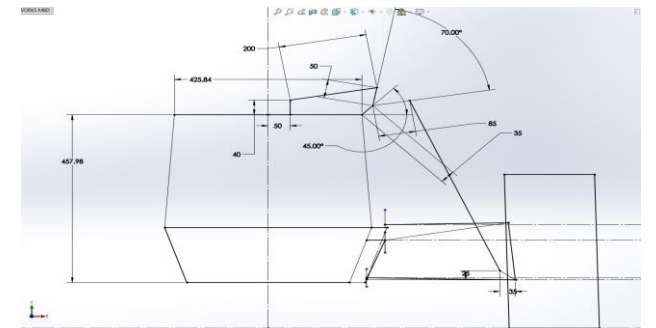


Fig -3: Rocker and pushrod geometry

These geometries cannot be finalized at a single go. They need to be modified until we get decent camber and toe curves. For this purpose, we need to simulate our experiments for getting better results and compare them for the best suspension geometry.

The use of simulation tools enable us to get better conclusions and meaningful results out of our experiments. Thus, the hardpoints in the suspension geometry are noted down and then imported in the simulation softwares for further assessment.

3. ANALYSIS AND VALIDATION

The hardpoints and the data from the suspension geometry in Solidworks is then imported in the ADAMS Car software by MSC Software. After importing, the quasi-static and dynamic simulations were carried out for studying and

optimizing the suspension geometries. The figures below show the results obtained.

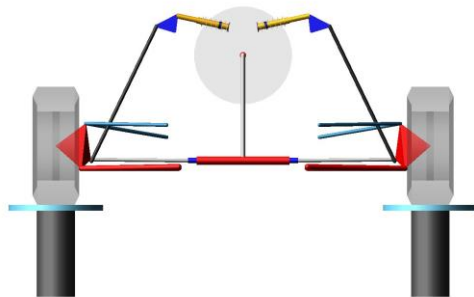


Fig -4: A set up of front suspension in ADAMS Car

by us and the Design of Experiments (DOE) was performed for taking us close to those results which reduced many of our iterations, hand calculations and also our time.

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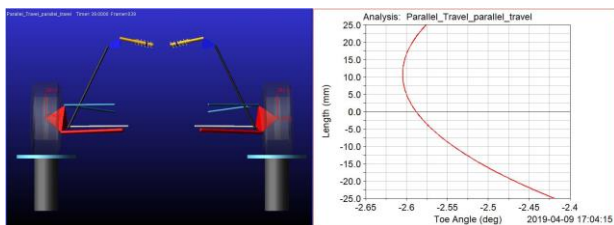


Fig -5: Optimizing Bump Steer Characteristics

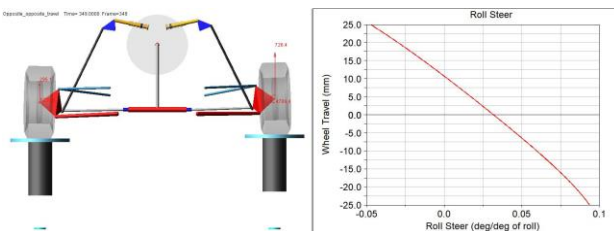


Fig -6: Optimizing Roll Steer Characteristics

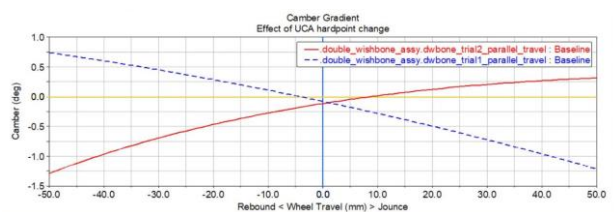


Fig -7: Optimizing Camber Gradient and setting up decent camber curves

For this, first the curve we need is to be decided and made in any tool like MS Excel or similar. This data can be used to visualize or compare with our study or results of the simulation carried out. Forces on the structural components can also be exported for a precise FEA to be carried out.

4. CONCLUSION

Simplifying the optimization of dynamics of the vehicle by using simulation tools was the main aim of the paper. The use of computational tools helped us a lot in designing, analyzing and optimizing the vehicle dynamics and suspension design. The results we needed were first defined