Optimizing Suspension System of an Fs Car and Improving Dynamic Performance by Quarter Car Model Simulation and Shock Dynamometer

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Abstract - **Since its inception, the team has always been striving hard to research, study, understand and implement the concepts involved in suspension to its full potential and extract the best out of the car on track. Prior to this season, exploring the possibilities involved in experimentation with the damper (shock absorber) and actual simulation of the entire system which would help us predict the ideal performance of the system in dynamic conditions is something which we haven't looked upon yet. Looking forward to this shortcoming as an opportunity to fill the voids in our approach towards designing the suspension geometry and extending our application of vehicle dynamics on the car, we aim to optimize the existing suspension system and improve the dynamic performance by doing kinematic analysis on simulink and utilizing the damper dyno characteristic curves. This paper proposes a method for improving handling characteristics and dynamic performance of an FSAE vehicle by performing a simulation on Matlab Simulink and studying the damper characteristics using shock dyno.**

Keywords –
Dependent suspension system, Independent suspension system, Pull rod suspension system, Camber, Damper, Damper characteristic, curves

I. INTRODUCTION

Suspension is a system of tires, springs, dampers, linkages (A-arms) that connect the vehicle's body to the wheels and allows relative motion between the two. This connection not only describes the path of relative motion but also controls the forces transmitted between the two. A Suspension system must serve a dual purpose which includes enhancing the vehicle's handling and keeping the occupant comfortable for all road terrains. A suspension system aims at achieving the three C's which comprise of Contact, Control and Comfort. Highly optimized suspension involves finding the right compromise.

Suspension systems can be broadly classified into two subgroups: dependent and independent: A dependent suspension normally has a shaft (live axle) that holds wheels parallel to each other and perpendicular to the axle. When the camber of one wheel changes, the camber of the opposite wheel changes in the same way by convention on one side this is a positive change in camber and on the other side this a negative change. An independent suspension allows wheels to rise and fall on their own without affecting the opposite wheel. Suspensions with other devices, such as sway bars that link the wheels in some way are still classed as independent. A third type is a semi-dependent suspension. In this case, the motion of one wheel does affect the position of the other but they are not rigidly attached to each other. A twist-beam rear suspension is such a system.

A. Problem Statement

The anticipation of Team Stallion Motorsport was to frame a formula student race car with high dynamic performance by upholding reliability. The revamping of the suspension system with the compact geometry and driver's ease was the primary demand. The opportunity and responsibility was to assemble prevailing comfort system, encouraged to design dynamically optimized, effectively tuned and fairly validated suspension system. The desire of the team to introduce new innovative ideas in the field of race car promotes to install suspension active aero package.

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B. Methodology

1) Approach: The approach enables to accomplish project efficiently, addressing both internal constraints and dynamic external situations in the interim. The approach was assumed to keep the project scope and goal stable till the project completion.
The phases laid down are:

- Project initiation and sponser
- Project planning and design
- Project monitoring and control
- Project execution
- Project completion
- Project testing
- Project validation

2) Designing of components and selection of materials: After identifying the problems related to the projects, the project work was embarked by designing the parts, analyzing the forces acting on them. The plan was to pick the material with high rigidity, high strength to weight ratio, and with less cost.

3) *Manufacturing of components:* The manufacturing was done with accepted production targets such as

- Minimization of manufacturing errors
- Optimum usage of material
- To trivialize the cost of production.
- To downplay the compliances.

4) Assembly and Validation: The skill requirement and knowledge required for this unit are

- Ease in assembly and disassembly
- High quality fixture
- Inspecting and checking the final assembly for conformance to specification
- Analyze components life and quality

C. Organization of dissertion

To enhance the performance of car in the dynamic field by diminishing the previous fault was the reason for the selection of project in the area of suspension. To satisfy this aim, intense study in the dynamic arena and regarding up gradation of suspension geometry were accomplished. The scrutiny was done regarding the problems faced by FSAE teams. The cross examination was carried out with the help of mentors. Immense testing of components was carried out to know practically problem faced in assembly. Data Acquisition System was used to validate the static results.

II. BACKGROUND

Figure 1 – Pull rod suspension system

Pull-rod suspension is literally just push-rod turned upside down, they take all the internal suspension parts and flip them upside down, then mount them as low in the chassis as possible to help with center of gravity. This also means that the suspension arm can be mounted darn near horizontal with respect to the road which is much better aerodynamically.

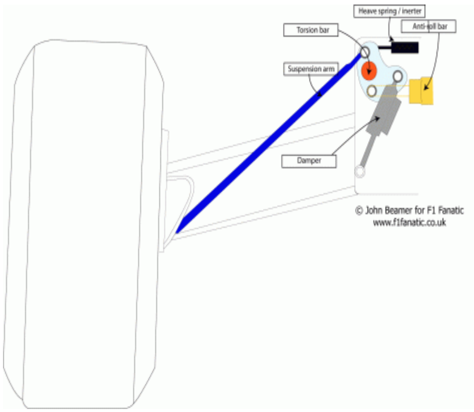


Figure 2 – Push rod Suspension System

In push-rod suspension, the suspension arm is usually at a ~45 degree angle to the bodyworks/tyre in an F1 car. When the car goes over a bump the movement is transferred through the tyre and rim to the suspension upright and then into the suspension arm, this then transfers the loads into the "actual" suspension.

No.	Parameters	Pushrod System	Pullrod System
1	Ride height	High	Low
2	Packaging/mounting	Easy	Complex
3	Weight of rod	More weight	Less weight
4	Stresses	Less stress on lower wishbone	More stress on lower wishbone
5	Adjustability	Easily adjustable	Relatively difficult

Table 1 – selection of subsystem

The aim of the team was to lower the C.G, centralize the weight, and reduce the weight of car. By considering all the above parameter the best suitable system fitted in the car was the pullrod suspension system. Hence the preference was to design pullrod suspension system.

The design aspect of the team Stallion Motorsport was started by presuming the values of track width, wheelbase, and C.G height and weight distribution of a car. The second stage was to allocate the budget after estimating the flow of money by providing flexibility in the design and innovative ideas.

The first stage in the design of suspension system was to provide suspension points to the chassis member from where the birth of chassis design was energized. The suspension points also known as hard points were simulated by using multifarious parameters like distance between C.G. height and roll center of the car, instantaneous center and scrub radius. The simulation was carried out on the Lotus software, different iteration were carried to obtain the optimistic value of roll centre and instantaneous center. The coordinates of hard points were finalized on the basis of optimistic car performance. The final coordinates were provided to the various departments for the designing process. The computational calculations were carried by assuming the suspension parameter values camber, castor, toe in, toe out, scrub radius in such a way that it provides better dynamic performance of the car. Adjustability was the primary goal while designing the suspension system which can provide different iteration while testing of the car . The tyre selection was done on the basis of traction, power which the car needs to run with its optimistic speed. With the collaboration the width for the front and rear wheel of the car was selected. According to Pat Clarke the racecar suspension system was designed by approaching the factors

- Reduce the weight
- Centralize the weight
- Lower the weight (Lower the C.G.)

The design was carried out for revamping the compliances in the assembly of suspension system which makes the suspension more functional and reduce unpredictable changes in dynamic performance of the suspension system.

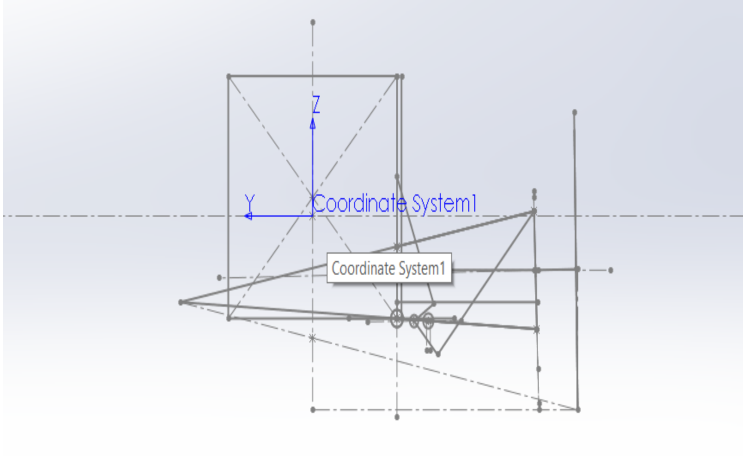


Figure 3 – Suspension geometry

Figure 4 – Manufactured A-arms

III. CALCULATIONS and ANALYSIS

Total weight(with driver 70 kg)	270 kg
Weight distribution (F:R)	40:60
Weight on front axle	108 kg
Weight on rear axle	162 kg
Total unsprung weight	38.11 kg
Sprung weight distribution(F:R)	49.4:50.6
Total sprung weight	231.89 Kg
Unsprung weight distribution(F:R)	40:60
Wheelbase	1.545m
Front trackwidth	1.150m
Rear track width	1.100m
C.G height from ground	0.28m

Table 2 – Calculations

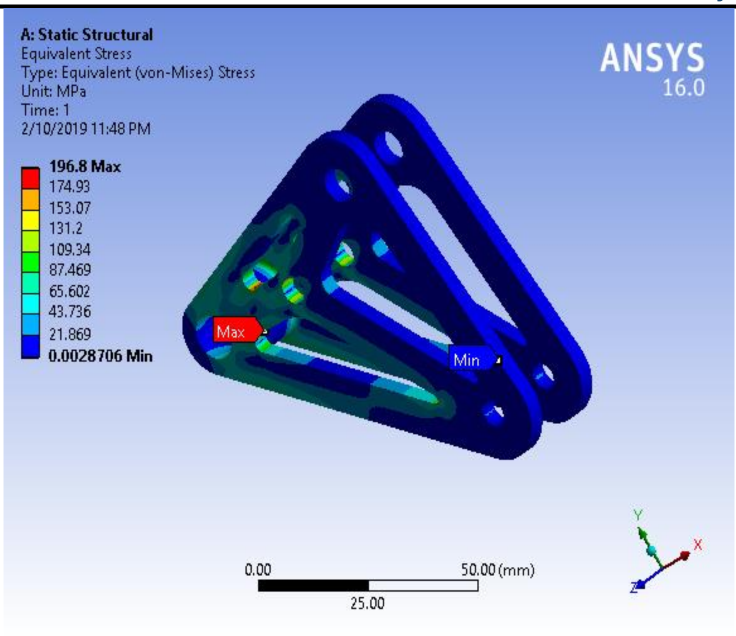
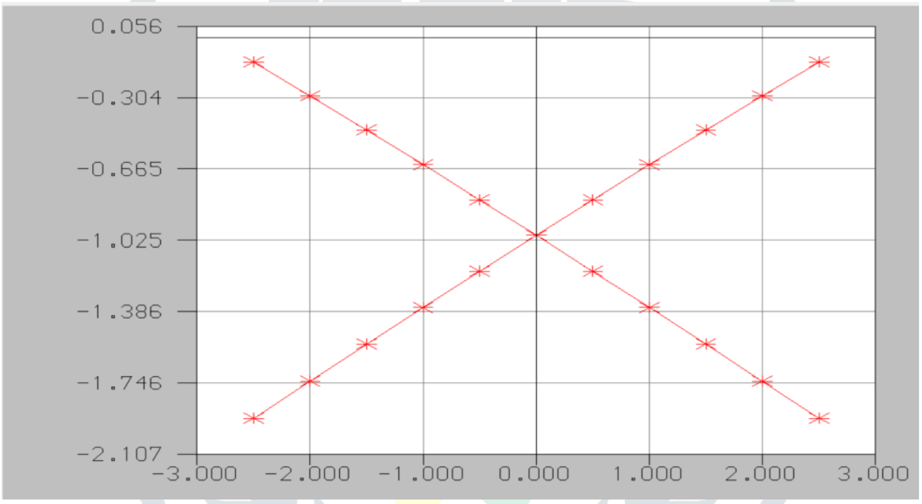


Figure 5 – Equivalent Stress on the Bell Crank



1	2.500	-0.1239	-1.9264
2	2.000	-0.2949	-1.7378
3	1.500	-0.4681	-1.5509
4	1.000	-0.6435	-1.3656
5	0.500	-0.8210	-1.1822
6	0.000	-1.0006	-1.0006
7	-0.500	-1.1822	-0.8210
8	-1.000	-1.3656	-0.6435
9	-1.500	-1.5509	-0.4681
0	-2.000	-1.7378	-0.2949
1	-2.500	-1.9264	-0.1239

Figure 6 – Roll angle vs Camber graph

IV. SCOPE OF PROJECT

- Determination of most efficient suspension configuration and geometry.
- Determination of spring and damper requirements.
- Determination of optimal values of camber, castor and king pin angles as well as scrub radius.
- Determination of attachment points at wheel, brake ,steering rack and chassis interface
- Design based of existing wheels and tyres
- Design synthesis and real time simulation of complete and functional suspension system.
- Maintain high level of adjustability for tuning of suspension system.

V. CONCLUSION

The team has designed an adjustable four link suspension system suitable to install on a race car. This suspension system can be adjusted remotely and can be done instantaneously. The advantage to the team design is the ease of adjustment and instantaneous adjustment capability that allows the suspension geometry to be changed while driving, to compensate for various dynamic loading. The design allows for an ease adjustment, while determining the performance output that the driver desire depending on the application. System flaws in the previous edition were accounted for and were rectified to enhance and optimize the performance all together.

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