Design and Analysis of Suspension System for a Formula Style Car

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Abstract

The paper aims to the study of Static and Dynamic parameter of Suspension System of a formula style car (F3 grade) by mathematical calculations. Also analysis has been done on simulation software. In order to produce the effect that would be faced by the suspension system when the real formula car will be running on the track during the event. Paper incorporates design and analysis of A-arm and knuckles for the suspension system for best possible results. Thorough investigation of previous participating cars has been done in order to find out the glitches and areas of improvements whereas the research was strictly circumscribed by FORMULA STUDENT INDIA rules and design requirements.

***Keywords*:** KPI, Camber, Caster, Scrub Radius, Roll Centre, Instantaneous Centre.

1. INTRODUCTION:

Formula Student India-International Level Event, also known as FS-IND is a design competition which follows the standards of the prestigious Formula SAE/Formula Student competitions held across the world. Formula style car (F3 grade) is the lower division of Formula one racing car. Designed, Analyzed and fabricated entirely by the college students. Vehicle follows the rules and regulation set down by SAE international [7]. Generally, in a race car, double wishbone suspension due to its advantage of providing negative camber gain and compact design. However geometry of suspension is different for the front and the rear [1]. The design of suspension system is perplexed and in order to achieve this task a set of procedures has to be followed with meticulous approach. This paper presents the procedure of design and analysis of A-arms, uprights of double wishbone geometry.

2. DESIGN APPROACH:

Choosing suspension geometries and components involves a wide range of choices and compromises. An analysis of the tire, chassis and road interaction is required to decide the trade-offs that will result in an optimum configuration for the type of vehicle and the nature of the race track for which the vehicle has to perform.

Basic steps in designing of suspension system are as follows:

- Selection of suspension type to be employed.
- Selection of wheels.
- Establish the vehicle's dimensions – wheel base and track width(s);
- Set up suspension parameters.
- Model the suspension geometry.
- Design components.

2.1 Suspension Type and Geometry Selection: Double wishbone independent geometry is selected due to:

- It is light and can be designed with a large freedom of adjustment.
- It produces negative camber gain.
- Compact design.

2.2 Wheel selection: Considering advantages and disadvantages of available wheels and factors like cost and availability, alloy rims of 13" diameter and 6" width with 32mm positive offset is to be used as it gives more space and freedom in the suspension design and brake components with proper clearance.

2.3 Wheelbase and Track width: keeping in mind the minimum space required for the packaging of vehicle subsystems the wheelbase was decided to be 1590 mm and a track width of 1370 mm at the front and 1200 mm at the rear.

2.4 Camber: Negative camber of 1 degree for the front and 0 degree for the rear is decided due to following reasons:

As negative camber is always recommended in front tires to improve cornering grip and providing better traction (but it should not be much that it will wear the inside contact patch during cornering) and in most situations the front camber value should be higher than the rear.

Rear camber should be as close to zero providing as much contact patch and grip to the rear as possible**.**

More camber is not recommended as it will lead to the instability of the car.

2.5 Caster: A positive 4 degree caster for the front wheels and zero caster at the rear wheels is decided.

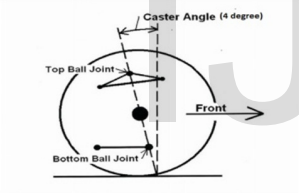


Fig 2.1 Caster

2.6 Kingpin Inclination (KPI): The kingpin angle for the car is set to be 7 degree for the front wheels and 0 degree for the rear giving a scrub radius of 25.92 mm for the front and 55 mm for the rear respectively.

2.7 Suspension parameters:

Frontal area	430 mm
Camber	-1 degree
KPI	7 degree
Scrub radius	25.92 mm
Spindle length	55 mm
Upper A-arm angle (with ground)	14.33 degree
Lower A-arm angle (with ground)	4.92 degree
FVSA length	1412.26 mm
Roll centre Height	20 mm
Instantaneous Centre	1412.26
Jacking Force	2.98 N
Ride Camber	0.040 degree/mm
Roll Camber	1.31 degree/degree
Body Roll(at max. lateral acc. i.e. 1.02g)	1.11 degree

Table 1. List of parameters

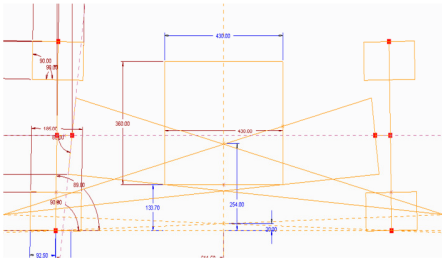


Fig. 2.2 Front suspension geometry

2.8 Suspension Geometry:

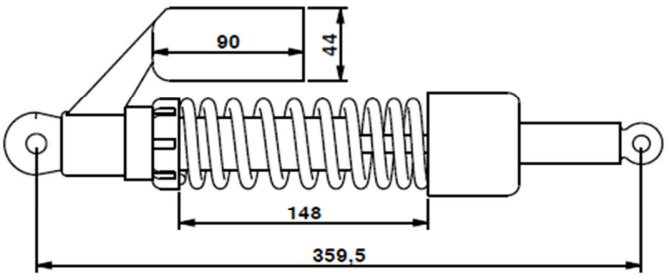
2.8.1 Front Suspension Geometry:

2.8.2 Rear suspension geometry:

2.9 Design of A-arms: CHROMOLY circular steel tube with OD of 16 mm and thickness of 4 mm (whereas previously it was 19mm in OD). CHROMOLY was selected due to its light weight and high strength, it can be easily machined and welded, and most importantly it is inexpensive and easily available.

(All dimensions are in mm.)

2.10 Shock Absorbers: The shockers used are nitrogen filled monotube shockers, with the spring rate of 14.875 N/mm and 18.162 N/mm respectively.



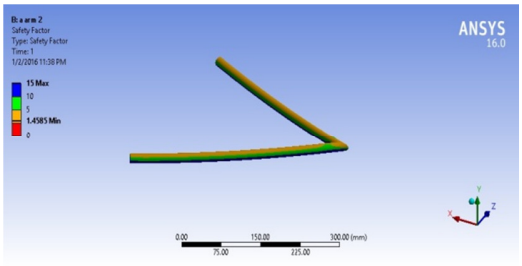


Fig. 2.6 Rear shock absorbers

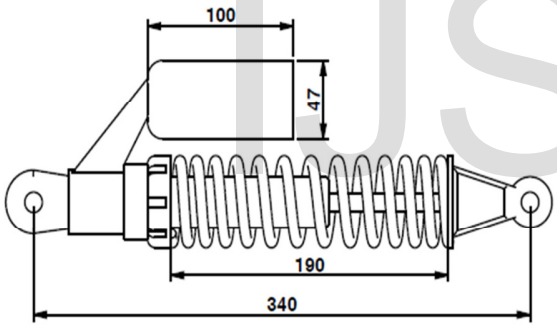
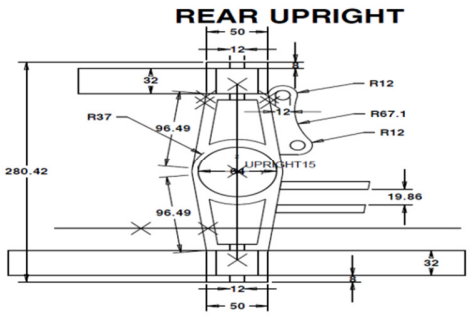


Fig. 2.5 Frontal Shock absorbers



2.11 Design of Upright: Uprights are designed at Creo.

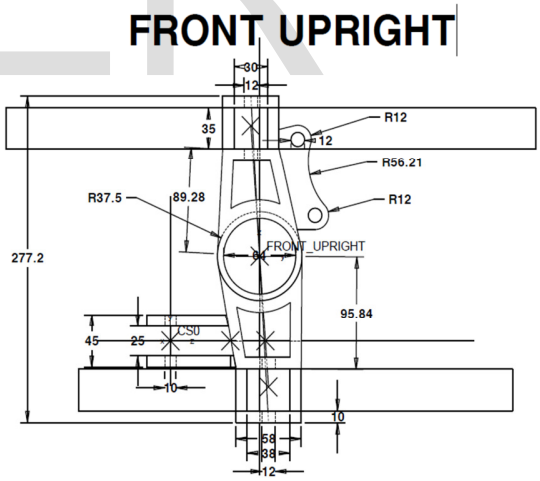


Fig. 2.7 Frontal upright

3. ANALYSIS:

Testing analysis of designed suspension system was done two times, prior to fabrication and after installation on FORMULA CAR during testing on track. The various parts were modeled on the simulation software (ANSYS) first in order to get acquainted about the

assembly, fabrication and possible upcoming difficulties in fabrication. The second and undoubtedly most important advantage of modeling was to check the system for any possibility of failure during its functioning. Simulation software gives the details about the stress distribution under static and dynamic loading circumstances.

3.1 Analysis of A-arm: Figure 3.1 shows the analysis of a-arm (wishbone) designed for the suspension system. It can be observed from the analysis that design is safe for fabrication. Stress in evenly distributed throughout the wishbone and far below the critical value.

Fig 3.1 Analysis of A-arm

3.2 Analysis of Upright: Figure 3.2, 3.3, 3.4, 3.5 depicts the analysis of uprights. Because uprights provides supports the bearing and ultimately the wheel rotates, thus it has to be strong enough in order to bolster the wheel and hub assembly. It can be observed that there are no red zones at the front or rear upright, though some yellow spots are present but it is far below the critical stress value for the failure of component.

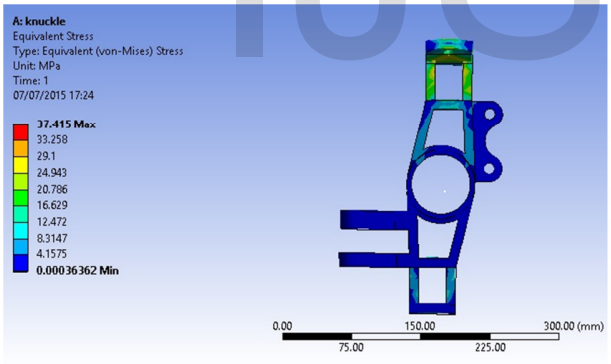


Fig. 3.2 Analysis of upright, view-1

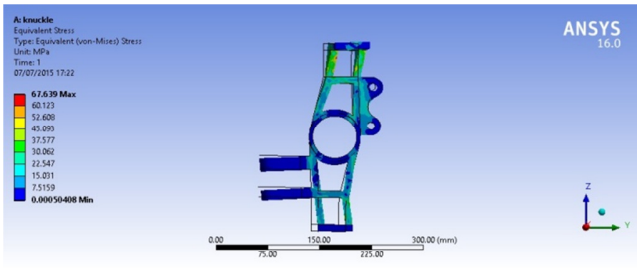


Fig. 3.3 Analysis of upright, view-2

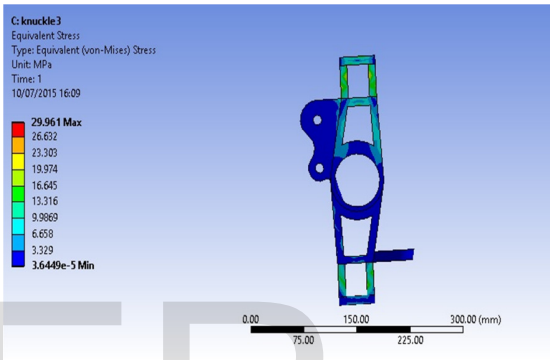


Fig. 3.4 Analysis of upright, view-3

4. RESULT

The Suspension system of the F3 grade formula car has been designed and analyzed based on the facts of vehicle dynamics. The primary objective of this paper was to identify the design parameter of a vehicle suspension system with the proper study of vehicle dynamics. This paper also helps to study and analyze the affecting parameters of suspension system. Thorough analysis of the suspension system yields the results as front roll Center to be 20 mm and rear roll center to be 40 mm. The results are optimum for better stability of car on track and comfortable ride for driver. Through the analysis it is clear that design is safe enough to step into the fabrication process.

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