International Journal of Recent Research and Review, Vol. X, Issue 4, December 2017

ISSN 2277 – 8322

Design and Development of Front-Suspension System of an Off-Road Vehicle

Tushar Digambar Tambe

M.Tech Research Scholar, VIT University, Chennai

Email: tushar.tambe05@gmail.com

***Abstract* - The main aim of suspension system is to isolate vehicle body from disturbance caused by road surface variation. In most of the vehicles passive types of suspension are used we started by determining the objectives of vehicle's suspension that must be fulfilled for BAJA Competition. Primary objectives of suspension system can be stated as achieve four wheel independence, achieve optimal camber compensation during wheel travel and cornering, there should not be toe change or at least adjustable toe change, there should not be compliance in the system, Weight should be minimum, avoid bump steer during wheel travel, achieve maximum contact patch for better traction, acceleration and braking, allow the driver to have complete vehicle dynamic control. Different options were available for suspension system at the front. After analyzing different types of suspension system, it was observed that the unequal length non-parallel double wishbone suspension system satisfies all the basic objectives of suspension system. Added advantage of using double wishbone suspension system is its weight. These design variables were finalized after carrying out various iterations with the help of CAD Software (CREO Parametric 2.0) and hence kinematic suspension performance goals are achieved.**

***Keywords* - BAJA, Double wishbone Suspension, All terrain. Vehicle**

I. INTRODUCTION

Different options were available for suspension system at the front. After analyzing different types of suspension system, it was observed that the unequal length non-parallel double wishbone suspension system satisfies all the basic objectives of suspension system. Added advantage of using double wishbone suspension system is its weight. The weight of the system can be optimized without compromising its reliability. Also packaging of the wheel assembly eases with the use of double wishbone system. The other objective of suspension system includes to achieve optimal camber compensation during wheel travel and cornering, there should not be toe change or at least adjustable toe change, weight should be minimum, to avoid bump steer during wheel travel, to allow the driver to have complete vehicle dynamic control [1-2].

II. ASSUMPTIONS AND BASIC TERMINOLOGIES

For carrying out various iterations certain parameters were needed to be assumed which are tabulated. Important parameters like Castor angle, kingpin inclination & Camber angle determine the dynamic behavior of the vehicle and must be understood properly before starting with the designing of suspension system.

Table I

Assumptions

Parameters	
Track width	48 inches
Wheel Base	56 inches
Ground Clearance	10 inches
Castor angle	9 deg
Kingpin inclination	8 deg

A. Castor Angle:

Caster angle can be defined as the angle made by the kingpin in the side view with the vertical axis passing through the wheel center [3]. Castor angle is shown in fig.1.

Effects of castor:

Castor angle is very influential parameter in the dynamic behavior of the vehicle. It is stability oriented property and is responsible for steering centric restoring force i.e the amount of castor affects the feel of steering and the amount of efforts required to turn the wheel. Fig. 1 shows positive castor angle.

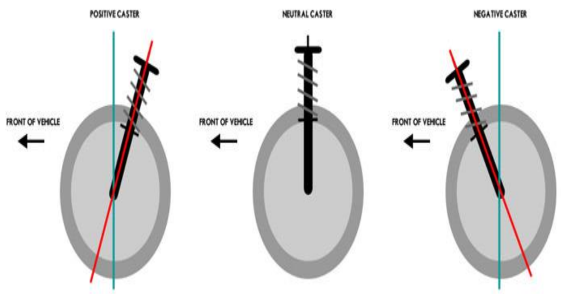

Fig. 1. Castor Angle

When the kingpin axis in the side view is extended further, it intersects ground at a particular point, the distance between that point and center of the contact patch is called castor offset or castor trail. Castor trail affects the resisting driver effort. Some amount of castor trail is required for reducing driver effort.

B. Kingpin Inclination

Kingpin inclination is defined as the angle at which kingpin axis is inclined to the vertical axis passing through the wheel centre [4].

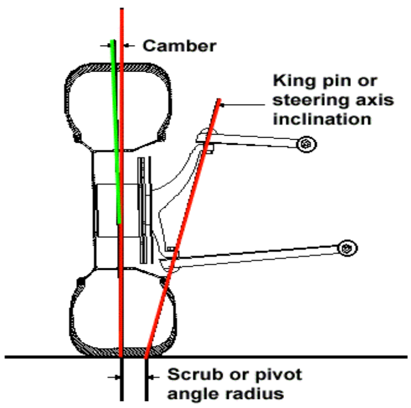

Fig. 2. Kingpin inclination, Scrub Radius and Camber

Effects of kingpin inclination:

Kingpin angle affects the performance of the car when the wheels are steered. More the kingpin angle more the car will lift when steered. When the kingpin axis is extended up to the ground, it intersects the ground at a particular point. The distance of that point from the centre of wheel contact patch is called scrub radius. Scrub radius increases the wear of the tyre but some amount of negative scrub radius is required so that the wheel purely rolls when steered.

C. Camber

Camber is another important parameter in dynamic behavior of the vehicle. Camber is defined as the angle between a tilted wheel plane and the vertical. It is one of the important terms which describe the suspension's alignment. Camber angle can have both negative as well as positive orientation. Camber is considered positive if the top of the wheel leans outwards and negative if the top of the wheel leans inwards. Camber is shown in fig.2 [4].

Effects of camber:

If a vehicle's wheels are properly cambered, a beneficial thrust force is produced. This thrust force, aptly named as camber thrust, contributes a lateral force in the direction of tyre's tilt. In other words, it ensures stability by pulling the bottom of the tyre in the same direction in which the top is leaning.

D. TOE

Toe is final parameter used to describe a vehicle's alignment. Toe is the symmetric angle that each wheel makes with the longitudinal axis of the vehicle, as a function of static geometry, kinematic and compliant effects. Tyre wear is heavily dependent on the toe distances. Dynamic factors induce change in toe which lead to two conditions- toe in and toe out as shown in the fig. 3 [4].

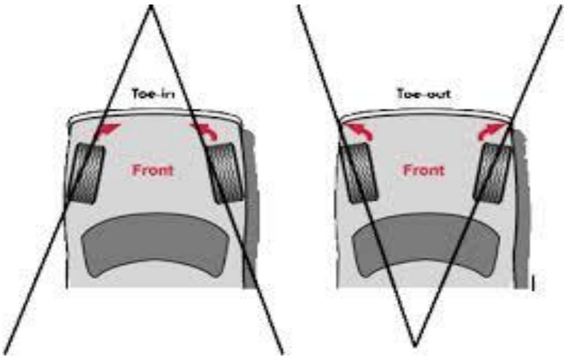

Fig. 3. Toe setting

Effects of toe:

In rear wheel drive cars, increased front toe in provides greater straight-line stability at the cost of some sluggishness in steering response.

E. Roll Centre

The Roll Centre of a suspension system is that point in the transverse plane of the axles, about which the sprung mass of that end of the vehicle will roll under the influence of that end of the vehicle will roll under the influence of centrifugal force [4].

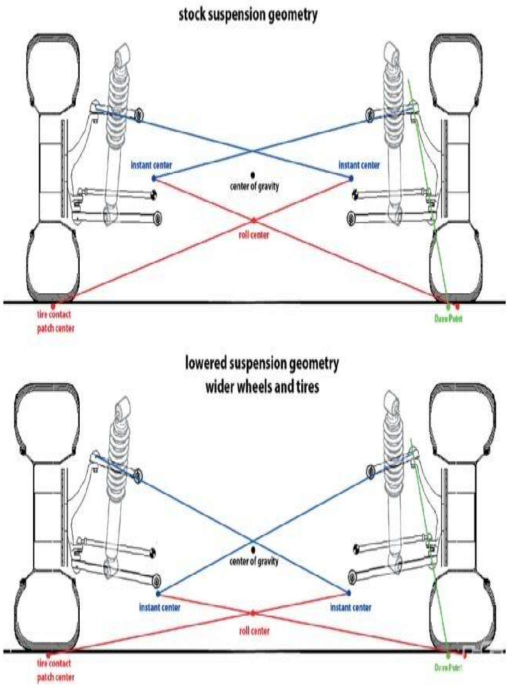

Fig. 4. Finding Roll Centre with the help of ICR's

F. Roll Axis

The straight line joining the front roll centre with the rear roll centre is called Roll Axis. Fig. 5 shows Roll axis [4].

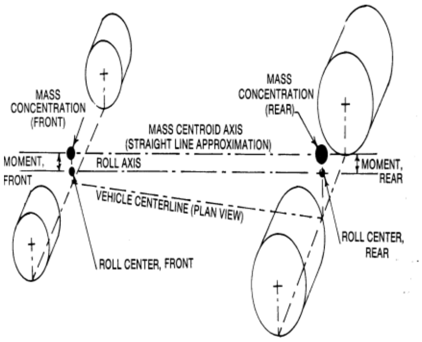

Fig 5: Roll Axis

III. DESIGN PROCEDURE

The Control arms serve as two of the four links in A-Arm suspension, the other two being the knuckle and chassis (ground). With the geometry of the knuckle chosen, the track-width defined, the only remaining design variable was the length of the control arms and their point of attachment to the chassis. These design variables were finalized after carrying out various iterations with the help of CAD Software (CREO Parametric2.0) and hence kinematic suspension performance goals are achieved. With the help of concept of instantaneous centers, various design variables like length of both wishbones, tie rod and rake angles were determined.

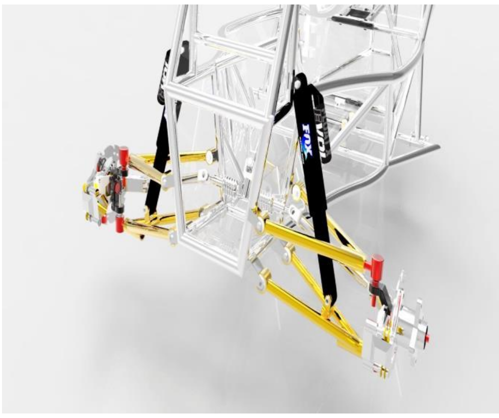

Fig. 6. Double Wishbone suspension system

This geometry results in approximately 7.23 degrees negative camber gain at 6 inches wheel travel in compression and 2. Degrees positive camber gain at 3 inches wheel travel in droop. Considering strength as the high preference factor, the lower control arms were designed using 2 mm thickness 1.25 inch AISI 1018 tube while the upper control arms were designed using 1.2 mm thickness 1.25 inch AISI 1018 tube.

Design for Manufacturing and Assembly (DMA):

(1) Installation Ratio: Installation ratio is decided by using space available on member between the lower wishbone which gives proper force transmission and sufficient gusset.

(2) Steering Angle: The full droop and jounce conditions are synthesized in CAD Software and extreme angle is calculated so as to avoid angles greater than 12^0 for proper force transmission.

IV. SIMULATION

The most important stage after designing is the simulation part. Simulation of the suspension system was done in MSC ADAMS Car software. Results of Simulation of suspension system can be seen in graphs shown below:

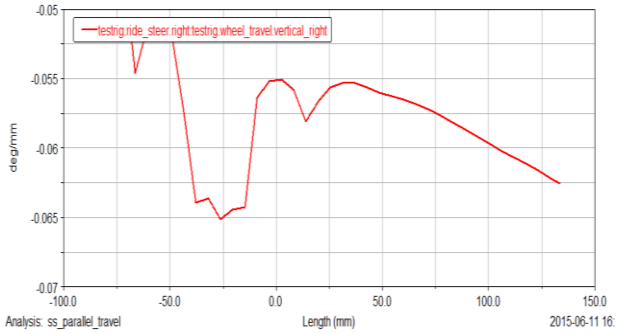

Fig. 6. Bump Steer

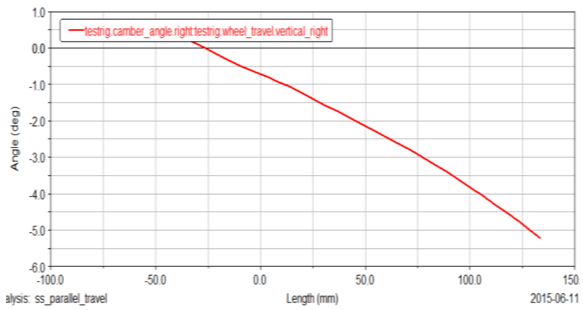

Fig. 7. Camber angle

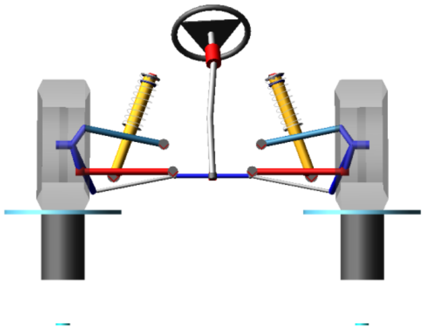

Fig. 8. Adams car Simulation

V. ANALYSIS

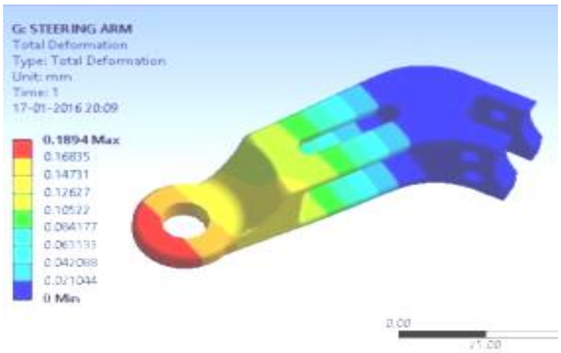

Fig. 9. Bump Steer

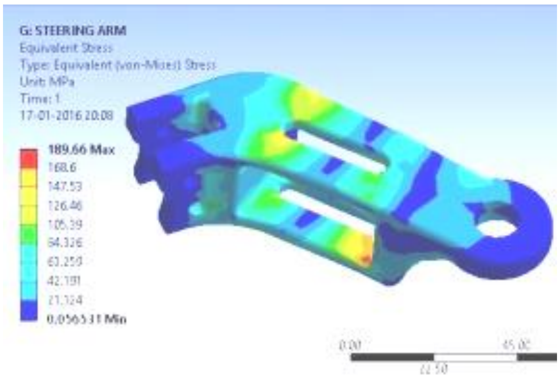

Fig. 10. Bump Steer

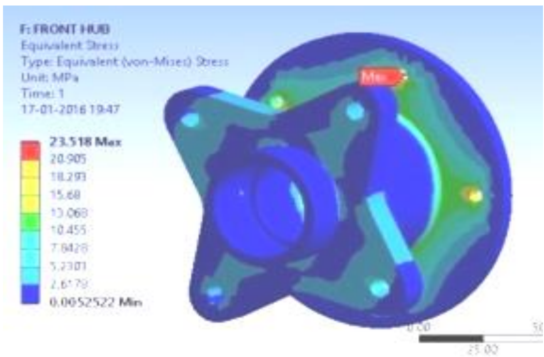

Fig. 11. Bump Steer

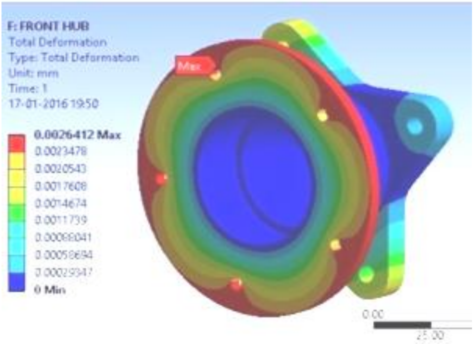

Fig. 12. Bump Steer

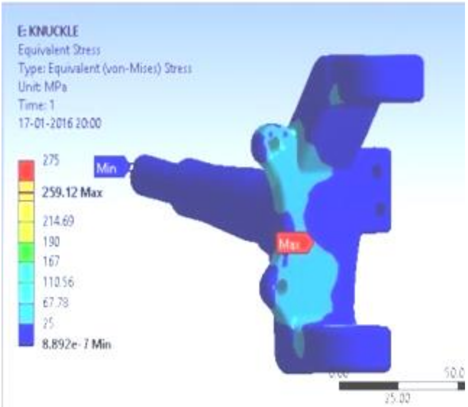

Fig. 13. Bump Steer

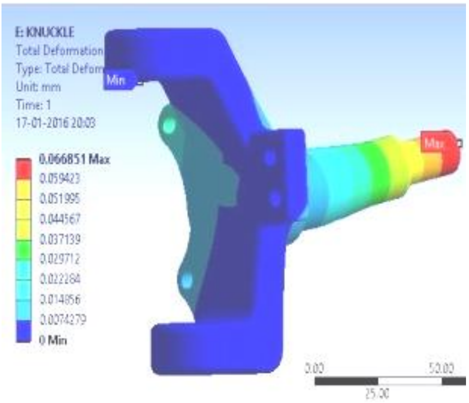

Fig. 14. Bump Steer

Table II
Results

Components	Stress(Mpa)	Deformation(mm)
Steering Arm	189.11	0.18
Hub	23.51	0.002
Knuckle	275	0.066

VI. Results and Discussion

The double wishbone suspension designed proved to be much more stable and the bump steer also has been avoided. The forces obtained in ADAMS/Car have been applied to the components. The components have been optimized in order to get minimum deformation and stress.

Fig. 15. Bump Steer

Fig. 16. Bump Steer

VII. Conclusion

The aim of the project was to design suspension of an ATV and incorporate them into the design of the vehicle. The chassis designed was simple, aesthetically stunning and very strong. The suspension was designed for 7”of wheel travel by means of using a double wishbone suspension with infinitely adjustable and progressive air springs. An Ackermann steering system was designed keeping in mind the driver’s feel of the vehicle and excellent cornering ability of the vehicle with no slip. During testing, if the chassis design was not strong enough or if it did not distribute the force properly, either the weld at the weak points in the chassis would have given away. However, absolutely no cracks were observed anywhere in the chassis. The 254 mm vehicle clearance and the curved members of the roll cage meant that the bottom of the chassis never hit the logs, rocks or bumps that the ATV went over. Thus, we concluded that the design, development and optimization of the suspension system include the thorough designing of the steering, actual suspension system and the wheel assembly of the vehicle. The design is optimized and developed according to a particular model of the ATV and satisfy the performance, reliability of the vehicle and the safety of the driver. The design is easy to manufacture and can be efficiently packaged in the vehicle. Testing and validation have proved that the objective of the project is satisfactorily satisfied.

VIII. REFERENCES

[1] Rulebook BAJA SAE INTERNATIONAL 2016.

[2] Chris Bennett, Eric Lockwood, Anthony McClinton, Robin McRee and Colin Pemberton "SAE Mini Baja Frame Analysis".

[3] William F Milliken and Douglas L Milliken "Race Car Vehicle Dynamics*", Milliken Research Associates, Inc*.

[4] Thomas D Gillespie; Inc. "Fundamentals of Vehicle Dynamics", *Society of Automotive Engineers*, 1992.

[5] S.S. Rao, Mechanical Vibrations, *Chapter 9, Edition 4th, Pearson, pp. 717- 734, 2004*