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Optimization and Effects of Suspension Parameter on Front Suspension of SAE Baja Vehicle using ADAMS

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***Abstract*—The main objective of a SAE Baja competition is to design and manufacture a sturdy ,versatile ,safe and maneuverable car for off-road application .The car should be designed with certain constraints from the rule book for its safety and they are optimized through various iteration and analysis to produce the best possible design .Suspension system is one of the most important because the design of the suspension determines the handling ,ride comfort ,load transfer ,Dynamic performance during braking, cornering ,straight line acceleration and safety of the vehicle.**

Keywords—Baja ,Double-wishbone ,ADAMS ,pro-dive,air springs , kingpin offset ,Recessional wheel travel

I. INTRODUCTION

The Baja India completion is conducted by the Society of Automotive Engineers(SAE) and are sponsored by Automotive giants like Mahindra ,Volvo etc .Students from various college in India participate in this competition .Baja competition takes place in a rough terrain and the vehicle is put through a series of obstacles and bumpy roads to test their dynamic performance and safety of the vehicle .A suspension is the system which separates the wheel and chassis and protects the driver from vibration and any impact .The main purpose of the system is to keep the tires in contact with the ground all the time.In order to get a good handling ,ride and dynamic performance its necessary to optimize the parameters like camber ,toe ,kingpin inclination ,roll center and instantaneous center height ,Caster ,Caster trail and Scrub radius.

II. FRONT SUSPENION

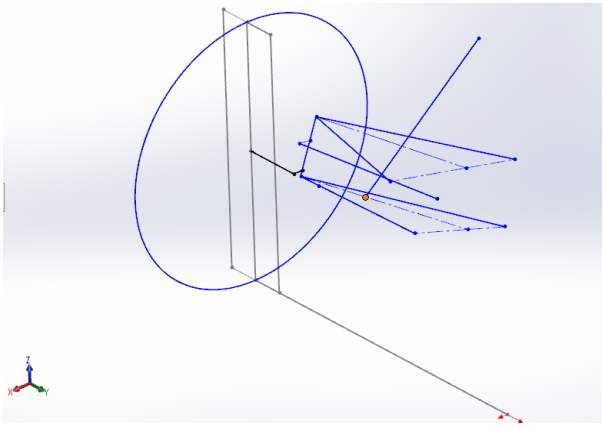
The front suspension of an automobile plays an important role in the dynamic performance of the vehicle .During the any event the front suspension of the car should provide enough traction to pull the vehicle through any rough situations and in events like maneuverability ,suspension and traction it is important that the vehicle should not roll over or loose traction during cornering .For off-road application its highly preferred to go for independent suspension so that the articulation of one doesn't affect the other wheel. The front suspension should be designed with a less unsprung mass in order to get the optimal ride performance

Selection of front suspension geometry:

Selection of the suspension geometry is very crucial because it cannot be altered, so in order to select the geometry various parameters were considered .These parameters include weight ,cost ,time to manufacture ,complexity of jigs and fixture ,clearance ,simplicity and familiarity .After a serious of consideration the front suspension that was chosen is unequal length, non-parallel double wishbone system .Double wishbone are chosen because it is easy to design and its cost to manufacture jigs and arms are also less .

Design Consideration for the front suspension:

1. The front track width of 51 inches and rear track width of 49 inches. The front track width is slightly larger than rearing order to improve the stability during cornering and provide enough roll resistance to the vehicle.
2. Ride height of 13 inches was desired so that the suspension system has more travel and navigates through the obstacles without bottoming out.
3. Roll center height at the front should be less than the rear in order to promote oversteering effect which is very useful during the maneuverability event.
4. The vehicle should have soft suspension in order to absorb the shock from the road input effectively and keep the driver safe. The shocks should be adjustable so that their spring rate can be varied for various dynamic event
5. The vehicle should have a minimum of 5 inches during a bump and 4 inches during rebound so that the driver stays safe from a sudden vibration and to provide comfort to the driver



CAD model of double wishbone

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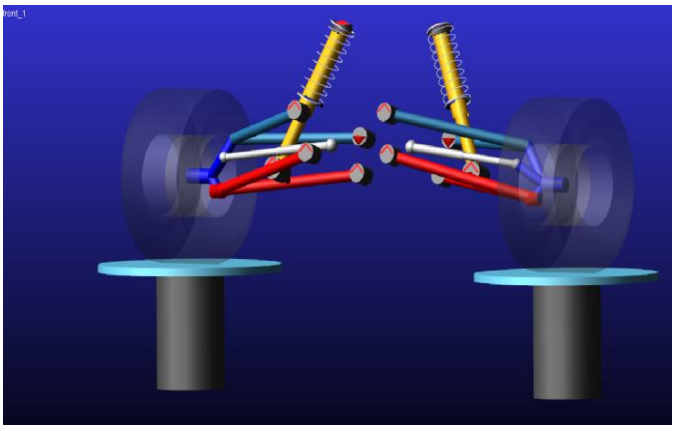
Kinematics of the vehicle:

The kinematics of the vehicle is how the vehicle behaves as it traverses through a range of obstacles and bumps .Suspension-parameters like camber, toe, caster, kingpin inclination, motion ratio and scrub radius affects the kinematic performance .These parameters affects the orientation of the wheels with respect to the ground which affects the handling characteristics of the vehicle .It's is necessary to provide the optimum range of values for these parameters to keep the tires in contact with the ground and also to prevent the tire from wear. The optimization of the kinematics of suspension was performed with help of MSC Adams and Solidworks. A CAD drawing of the front suspension was drawn considering the vehicle parameters, then these hard points were imported into the ADAMS/Car software and the analysis was performed. In order to provide wheel travel of 5 inches during a bump and 4 inches during rebound motion ratio of 0.5 was chosen. Motion ratio or Linkage ratio is the ratio of spring travel to that of the wheel travel. Reducing the motion ratio increases the travel but it increases the forces acting on the wishbone or lower a-arms .So the lower wishbone should be structurally optimized with FEA analysis.

The pro-dive geometry of 30% on the front was incorporated in order to transmit the forces to the shock effectively and it also provides a small amount of recessional(longitudinal) wheel travel .However it causes a large amount of forces to be transferred to the front during braking.

ADAMS/Insight was used in order to reduce the time of the iterative process. Once the desired roll centers are inputted, ADAMS/insight iterates only the selected hard points location to provide the optimal location of these hardpoints. So the final points were determined through the iterative process conducted by ADAMS/Insight and the graphs for the suspension parameters were obtained



Kinematic Model of Double wishbone in ADAMS/Car

Effect of the suspension parameters:

1.Camber:

Camber is the angle between the inclination of the wheel plane with respect to the vertical plane normal to the ground when looked from the front or rear view .camber affects the traction ,tire wear ,amount of camber thrust etc .The lateral force at the tire is caused due to both camber thrust and slip angle .Usually the lateral force due to camber thrust is less than the that due to slip angle .Effective cornering stiffness of the tire is addition of cornering stiffness(due to slip angle) and camber stiffness(due to camber angle).Positive camber decrease the value of camber stiffness whereas the negative camber increases the stiffness .So a negative cambered car has more effective cornering stiffness .The lateral capabilities of tire is increased when its effective cornering stiffness is increased .Since it can handle more amount of lateral force it corners smoothly and effectively without loss of traction .So a negative camber of -1 to -3 degree is preferred at static for off road condition .The camber gain should limit within 8degrees during bump and rebound ,because too much of camber degrades the tire performance and results in increased tire wear.

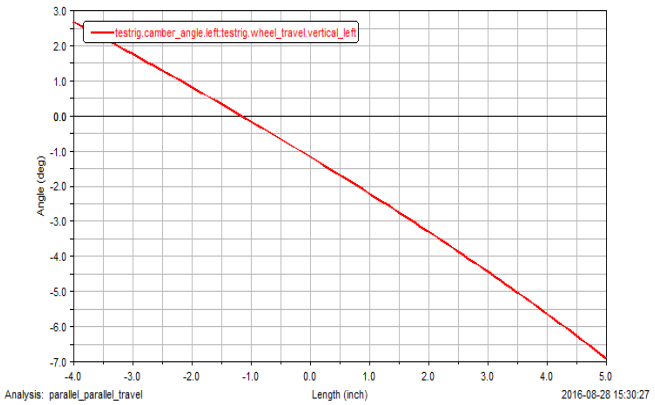


Fig 1 - camber angle

2.Caster:

Caster angle is the angle between the steering axis and the vertical plane when viewed from the side .Settling of caster angle affects caster trail which is the distance between center of contact patch and point at which steering axis intersects the ground .Caster angle causes the lift or fall of the tire during turning also it changes the camber and toe angle .The length of caster trail affects the self-aligning moment that acts through the steering axis .If the caster trail is more the wheels will align itself to the static position quickly but the effort required by the driver is more so optimum caster trail is selected .The value caster angle affects the caster trail ,so it's is important to optimize caster angle with respect to caster trail .A small amount of kingpin offset of less than 1 inch is desired to reduce the caster trail and increase the caster angle slightly .Usually for off road vehicle caster of +14 to +8 is preferred.

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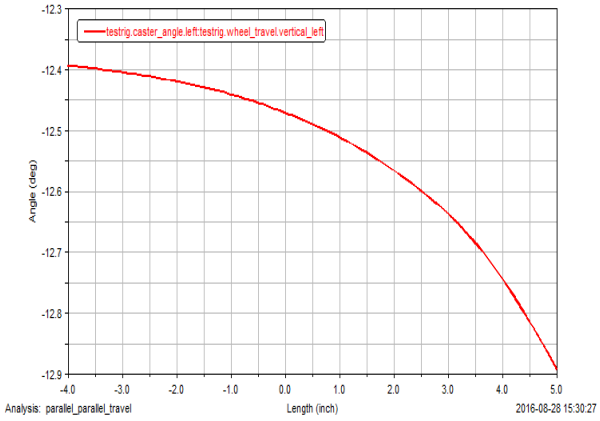

Fig 2 - caster angle

3.Toe:

Toe angle is the angle between the vehicles longitudinal axis and line passing through the center of the tire when viewed from the top .During acceleration or braking there will toe change due to the elastic deformation of the suspension components so it's necessary to preset an initial toe angle so that during the acceleration the tire straightens itself automatically .It is very important to optimize the toe change during the suspension travel as it may cause bump steer which is undesirable for off-road Baja cars.

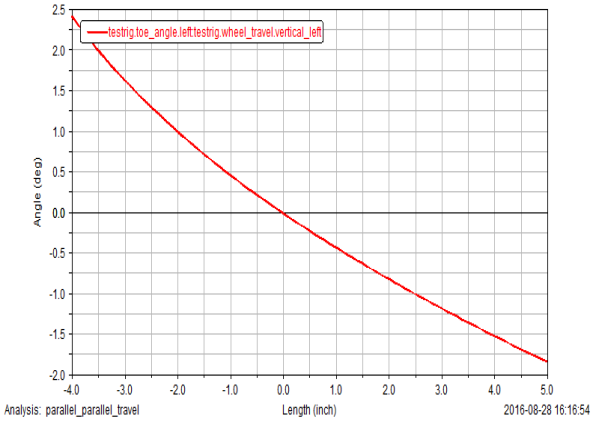

Fig 3 - Toe angle

4.Kingpin inclination angle and scrub radius:

It is the angle between the steering axis and vertical plane when viewed from the front .Kingpin inclination causes the wheels to rise or fall during turning .In case if the inclination angle is great ,then the rise and fall of the tire will also be greater and it also helps in tight turns .The distance between the ball joint also affects the rise and fall of the tire .Reducing the distance between ball joints transmit more force to the upper control arm and reduces the rise and fall of the vehicle .Usually positive kingpin inclination angle with negative scrub radius is preferred for off-road vehicle .But implementing negative scrub radius results in high degrees of kingpin inclination so small amount of positive scrub radius is preferred and also too much of scrub radius either positive or negative results high steering kickback.

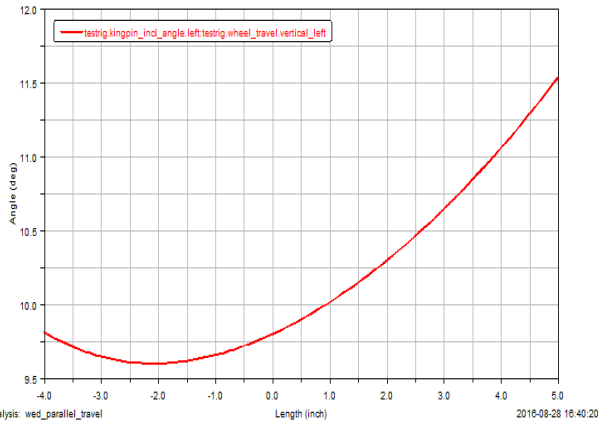

Fig.4 - Kingpin inclination angle

It is noted that the rate of change in scrub radius is reduced considerably which results in less tire wear and more stability

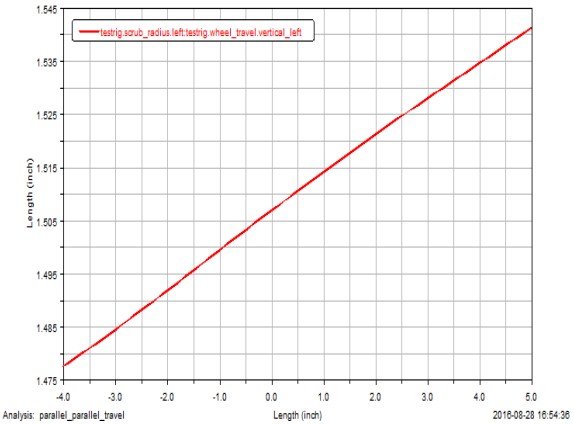

Fig 5 - scrub radius

5.Instantaneous center:

Instant center is the imaginary point about which the suspension system tends to pivot .The location of the instant center determine the camber gain ,track width change, roll center location and steer characteristics .Instant center in the side view determines the longitudinal wheel path ,squat/dive configuration ,caster change rate and pitch center .If the front view swing arm length is long then camber gain will also reduce ,so iterating the location of instant center by changing the hardpoints gives the desired camber gain .Height of the instant center determines the track width change .Generally the track width change should be minimized as much as possible .By keeping the instant center near ground and inboard reduces the scrub or track width change but the location of roll center will be below the ground ,which is not preferred .So proper compromise has to be made between instant center and roll center location.

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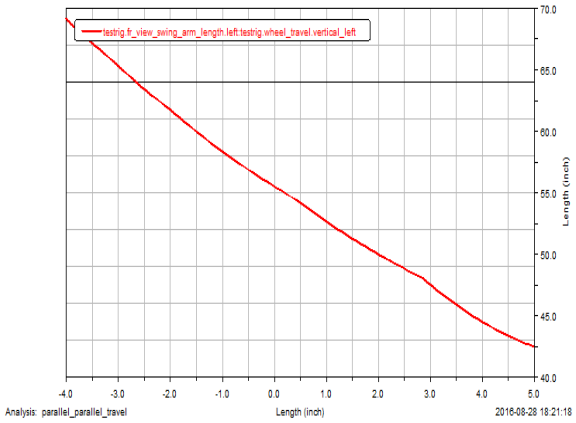

Fig 6 - Lateral location of Instantaneous center

6.Roll Center:

Roll center is the virtual point about which the vehicle tends to roll and also lateral force generated by the tire are transmitted to the sprung mass through this point. For off-road condition the front roll center is kept less than that of the rear in order to give oversteering effect to the vehicle. Lowering the front roll center lowers the roll moment resistance and also makes the wheel evenly loaded which increases the grip .Roll center should be optimized such that the jacking force is less than the lateral force at the tire or else jacking force may tend to push the sprung mass upward during cornering and causes the sprung mass to roll.It is necessary to check the lateral movement of the roll center at the front and rear such that they follow the same pattern or else the vehicle may experience yaw moment .The front roll center should be placed close to the center of gravity of the vehicle as much as possible in order to reduce the roll moment which is proportional to the distance between the center of gravity and roll center.

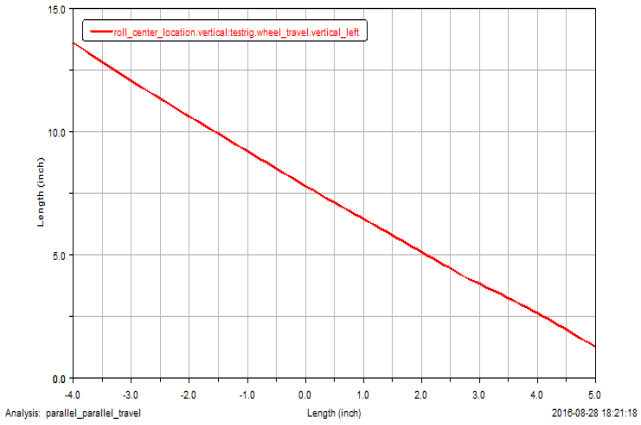

Fig 7 – Vertical Roll center location

7.Roll stiffness:

Roll stiffness at the front of the car is increased by slightly increasing the inclination of the shock, this promotes greater stability during cornering. Therefore, to determine the shock orientation the upper strut mount point was iterated to get the desired combination between wheel travel and stiffness. Increasing the front roll center promotes oversteering effect.

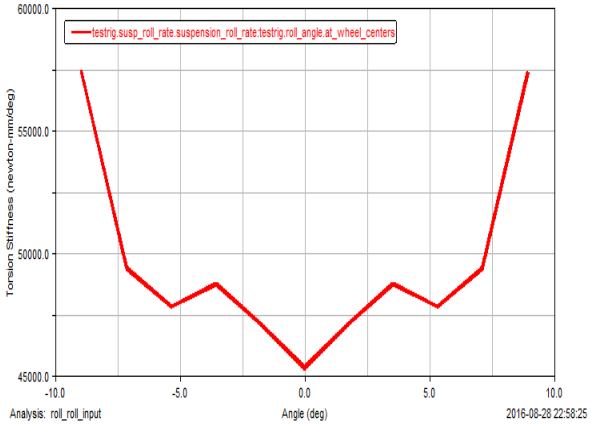

Fig 8 - Suspension roll rate

8.*Recessional wheel travel:*

The front double wishbone geometry is slightly tilted towards the rear in order to transmit more loads to the shock effectively as vehicle runs over the obstacles. This type of geometry at front gives 30% of pro-dive and it results in wheels moving longitudinally backwards. But it causes a large amount of weight transfer at the front which tends to make the vehicle dive forwards during braking. This type of suspension geometry allows the vehicle to go over the bumps and obstacles more easily.

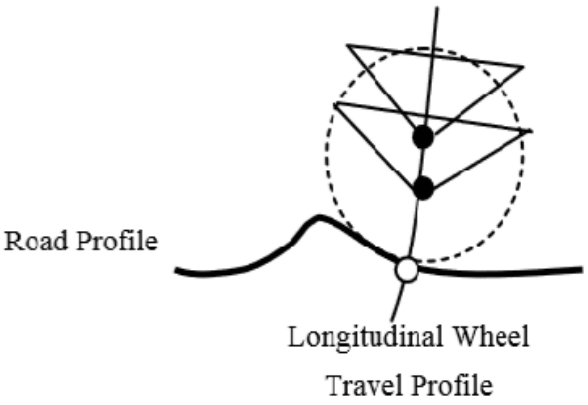

Fig 9- wheel profile

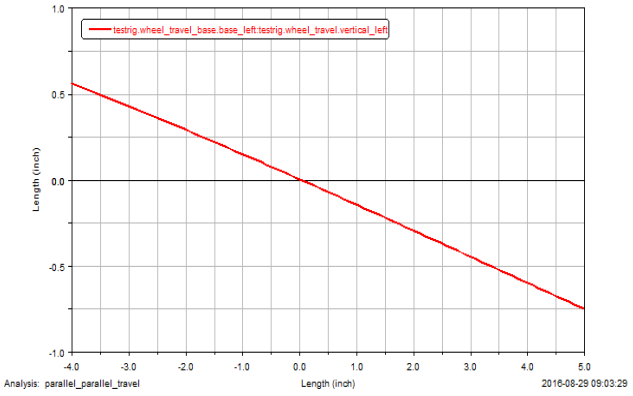

Fig 10 - longitudinal wheel travel

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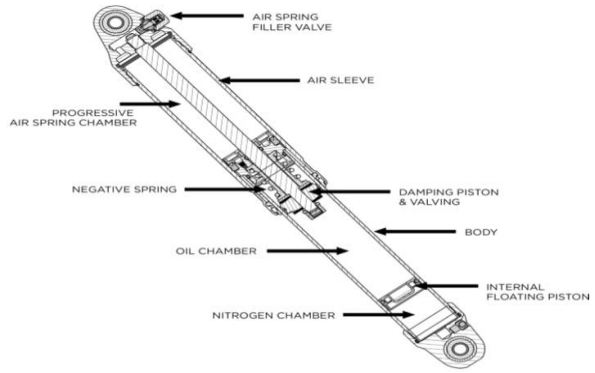
Selection of shock:

Shocks are one of the important components of the suspension system. The function of a Shocks is to transmit and absorb the forces generated in tire due to the rough road condition. It works by converting the kinetic energy absorbed from the wheel's motion to heat. Shocks usually consist of two parts, one is spring and the other is the damper. The spring portion of the shock is only capable of absorbing the shock and load of the vehicle whereas damper dissipates the energy stored in the spring and reduce the vibration.

The chosen shock for the Baja vehicle was Fox Float 3 where the coils are replaced by air springs, hence it has an infinity adjustable spring rate .However the damping of the shock cannot be modified .These shocks are made of 6061-T6 aluminum in order to reduce the weight and increase the strength of the shock. Air shocks are generally progressive, that is the force required to compress the shock increases exponentially. So for a small bump the shock provides sufficient travel and keeps the driver comfortable. For a large bump or fall of the vehicle the shock travels progressively and it prevents the vehicle from bottoming out.

The spring rate of air shocks are dependent on their air pressure.so in order to determine the air pressure, the values were extrapolated from the spring rate curve. A motion ratio of 0.5 was selected in get more travel. The spring rate data given in fox shock manual was inputted in ADAMS curve manager and simulation was performed.



Cross section of Fox float 3

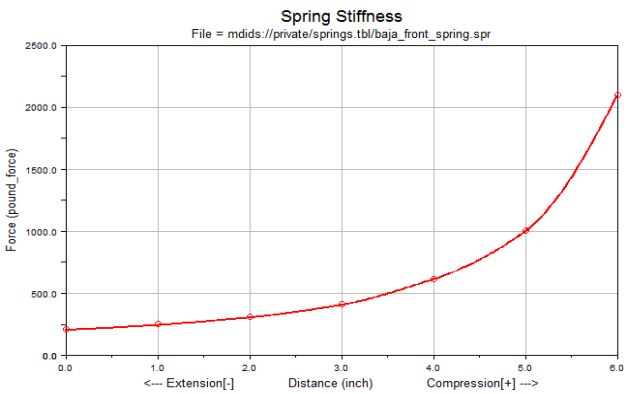


Fig 12 - Spring stiffness property file

III. CONCLUSION

Change in one Suspension parameter usually affects the other parameters, so a suspension designer should make the best possible compromise between the parameters .It is important to perform real-time testing and then change the spring rate, tire pressure accordingly to get the best result .ADAMS can generate graphs showing the maximum forces acting on the components ,using these graphs FEA simulation is performed to optimize these components in terms of weight and strength .The values obtained are within the limits so results obtained is successful .

IV. REFERENCE

[1] Dixon, John C., (1996) Tires, Suspension and Handling, Warrendale, PA: Society of Automotive Engineers
[2] Milliken, William F., Milliken, Douglas L., (1995) Race Car Vehicle Dynamics.
[3] Fox Racing Shock Manual: FLOAT 3 Factory Series Owner's Manual
[4] Adams Manual and Software Package
[5] Previous year design report
[6] V.V. Jagirdar*, M.S. Dadar, and V.P. Sulakhe. Wishbone Structure for Front Independent Suspension of a Military Truck. Defence Science Journal, Vol. 60, No. 2, March 2010, pp. 178-183