Optimisation of Camber Angle for Better Ride Comfort and Vehicle Handling using ADAMS CAR

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Abstract— Inspiring from multibody dynamics this paper has been carried out for estimating the dynamics of vehicle in motion. As there is more and more importance is given to the handling performance to the vehicle for its comfort, here we have considered camber angle as the main parameter and we have studied, analysed the change for increasing the overall performance and vehicle behavior. Focus of our project is to find the optimal camber angle on double wishbone geometry for ride comfort and vehicle handling. Force analysis was done for 0, 2 and-2degree camber angle at 0.4g cornering using ADAMS CAR software.

Keywords— Camber, Ride Comfort, Vehicle Handling, Double Wishbone

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'swhich comprise of Contact, Control and Comfort. Highly optimized suspension involves finding the right compromise.

A model is constructed in ADAMS/CAR to simulate test condition and predict the results for the test to be conducted. The prediction of this model is verified with calculation results from literature. An Open loop estimator that uses 3 degrees of freedom vehicle model is used to estimate results using real-time time data from simulations. We conclude that a 3 degree of freedom model is a good start for using estimation technique for vehicle dynamics and vehicle performance.

Fig. 1. Double Wishbone Geometry

II. Force Calculations

All the below shown figures indicate the force obtained form force calculation on double wishbone geometry. Initially the reactions were calculated on ball joint using front view of the geometry. Later these reactions were used to find the forces in upper and lower arm using side view and top view. Sturt force was calculated using geometry after the forces obtained in A-Arms.

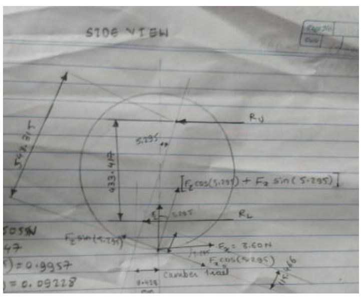

Fig. 1Side View

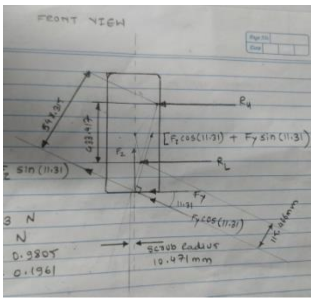

Fig. 2. Front View

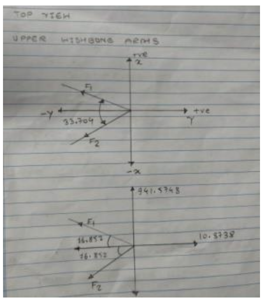

Fig. 3. Top View

Sample Calculation;

$\sum M_{@R4} = 0$ VE+ CLOCKWISE

$-[F_Z \cos(5.295) + F_X \sin(5.295)]*(9.428) - [F_X \cos(5.295)]*(548.315) + [F_Z \sin(5.295)]*(548.315) + R_L*(433.417) = 0$

$\sum M_{@RL} = 0$ VE+ CLOCKWISE

$-[F_Z \cos(5.295) + F_X \sin(5.295)]*(9.428) - [F_X \cos(5.295)]*(115.466) + [F_Z \sin(5.295)]*(115.466) + R_L*(433.417) = 0$

	0 Degree Camber				
	Outer		Inner		STRUT
	UCA	LCA	UCA	LCA	
ADAMS	1613	1675	70	756	3598
CAL	1526	1814	98	1058	4600

Fig. 4. Calculation Table From FBD

III. HALF CAR SIMULATIONS

For simulation of suspension system,ADAMS CAR Software was used. Initially, simulation for quarter car model was carried out. After simulating quarter car, half car model was built according to hard points given. The geometry of the suspension system is very much dependent on steering system. So assembly for steering and suspension in half car model was considered for further simulation Rack & pinion Steering subsystem is used for half car model. For different geometry, suspension behaves differently leading to necessary changes are required in components like lower control arm, upper control arm, spring upper pivot, damper lower pivot, rack & pinion, tie rod, steering wheel.

After giving hard point required we have specified installed length of spring equal to 145.75 mm. In the suspension parameters window, we have specified the tire unloaded radius 315.8mm. Tire stiffness was given 200N/mm. we have specified sprung mass equal to 1500kg. Also, CG height was maintained at 401 mm. wheelbase was considered according to data equals to 2560mm. we have specified braking ratio 50:50.

For the suspension analysis parallel travel condition was simulated. Bump travel was considered equal to 100mm. The rebound was specified equal to -100mm with respect to wheel centre. In animation control simulation was verified as per our designed geometry.For getting visual representation animation control panel is used but for getting a greater number of results of vehicle performance graphical representation is required. In (mdi suspension parallel travel. plt) file we got most appropriate graphs for riding comfort. Graphswere analysed for camber vs wheel travel, caster angle vs wheel travel, toe vs wheel travel, wheel rate vs wheel travel. From the graph we have got the results for inclination angle.

IV. FULL CAR SIMULATIONS

Full car simulation was carried out for cornering condition at constant radius cornering at 0.4g lateral force.For the cornering event we have simulated our graphs at -2,0,+2 camber. For the simulation constant 0 camberwas considered at rear wheels. Simulation was performed for 35 m turning radius at gear position 3. Lateral acceleration was consider as 0.4g.In the graphs we have checked lower control arm force vs time, lower strut force vs time, top mount force vs time, upper control arm force vs time.

Left Tyre (Inner)

Right Tyre(Outer)

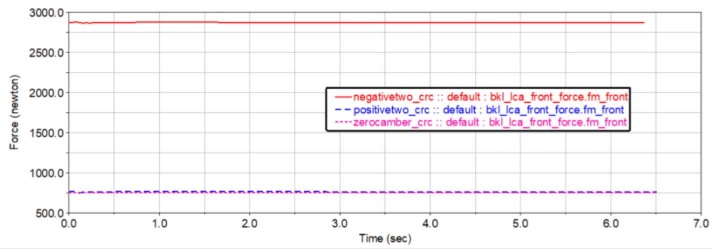

Fig. 5.Lower Control Arm Front Force

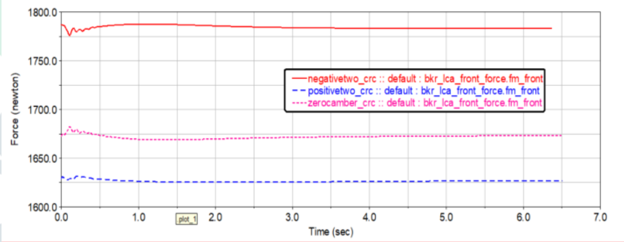

Fig. 6.Lower Control Arm Front Force

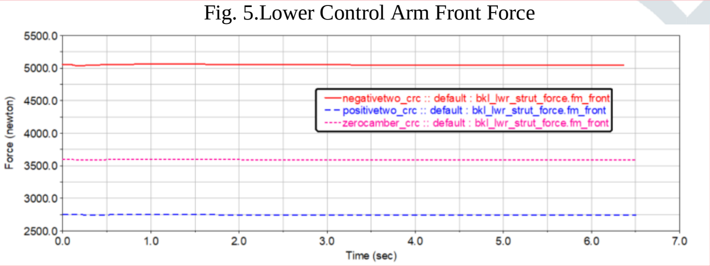

Fig. 7.Lower Strut Force

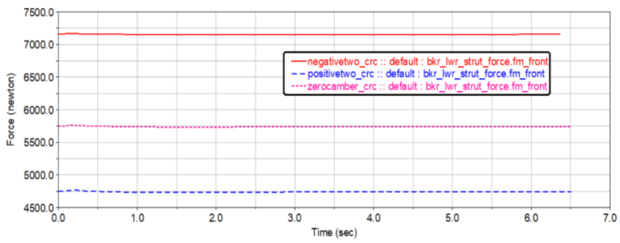

Fig. 8.Lower Strut Force

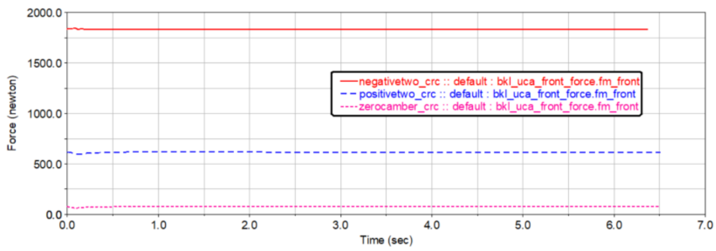

Fig. 9. Upper Control Arm Front Force

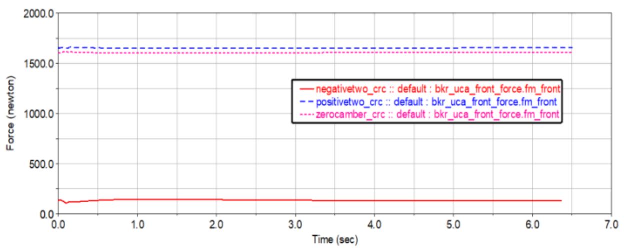

Fig. 10. Upper Control Arm Front Force

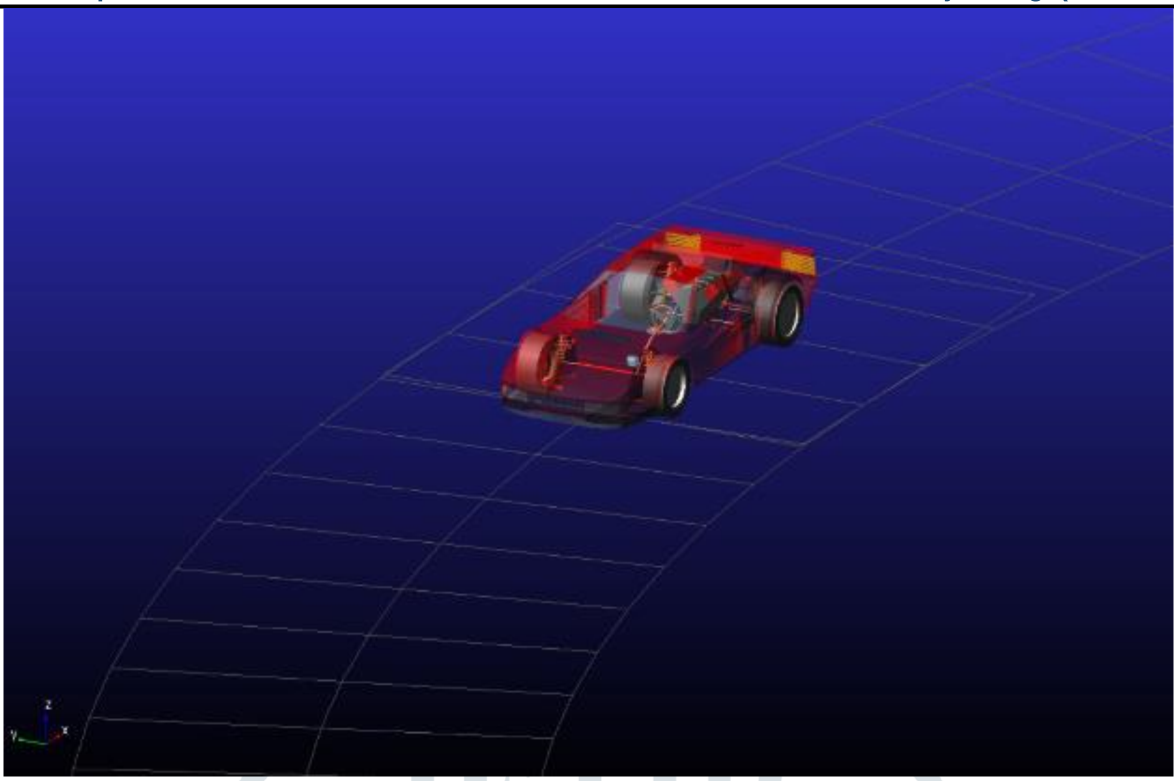

Fig. 11. Full Car Simulation For
Constant Cornering In Adams

V. Ride Comfort And Vehicle Handling

Parameters for Ride comfort and Vehicle are indicated below. These parameters are dependent on forces arising on suspension system and one of the maximum forces are seen to occur at cornering event of vehicle.

- Influence of camber and tire pressure-
  Low tire pressures, road holding becomes very high as the tire won't be able to retain its true shape which in turn increases the area of the tire-road contact patch. Change in camber has little impact in case of deflated or underflated tires. In case of overinflated tires, the perfectly round tires maintain only a point contact with the road as predicted by the geometry; thus reducing the road holding ability. A slight positive camber tends to increase road holding. At low tire pressures, the driver experiences negligible comfort and the ride becomes harsh. The ride comfort is at the peak at high inflation pressures, regardless of the variation in camber.
- Interaction of spring stiffness and tire pressure-
  As stiffness increases, road holding decreases for same values of tire pressure. It can also be observed that road holding also decreases with increase in the tire pressure. In accordance with the generally observed phenomena, the ride becomes stiffer and harsher with stiffer springs and low tire-pressures. The ride comfort improves drastically by implementing high inflation pressures and softer springs.
- Interaction between toe and tire pressure-
  In case of tires having a formidable amount of toe-in, it is very difficult for tires to leave contact with the ground.
  Irrespective of the tire pressure, increase in the magnitude of toe-in unsettles the ride of the vehicle. In case of excess toe-in, the ride is too hard at low pressures. A slight toe-in when incorporated in tandem with high inflation pressures greatly improves the quality of the ride and boosts driver comfort
- Interaction between sprung mass and tire pressure-
  In case of over inflated tires and moderate loads, road holding decreases but increases with increase in sprung mass as is evident from load carrying trucks. Sprung mass has a direct influence on road holding. Regardless of the magnitude of sprung mass, low tire-pressures translate into bitter ride-comfort. However, at high inflation pressures, a high degree of comfort is experienced if the sprung mass is relatively low
- Interaction between spring stiffness and camber-
  For positive camber, road holding remains pretty high and is not affected much by the variation in stiffness.Considering of the impact of the same interaction on ride comfort it is seen that even vehicles with stiff springs can be provided a supple ride by inducing a significant positive camber. Increasing camber has got a tremendous influence on improving the ride quality of the vehicle.
- Interaction between damping coefficient and camber-
  As damping coefficient decreases, the road holding increases. At a slight positive camber and low damping coefficient, maximum road holding is observed. With a large magnitude of camber, road holding decreases with an increase in damping.A high damping rate clearly implies better ridethe comfort level increases with increase in the magnitude of positive camber imparted to the wheel.
- Interaction between toe and camber-
  Toe-in and positive camber render maximum road holding ability to the tire under all circumstances provided, all the parameters are unchanged. This interaction is insignificant for ride comfort.
- Interaction between mass and camber-

For moderate masses, road holding doesn't change much with change in camber. When the vehicle is heavily loaded the road holding decreases slightly with increase in positive camber as the increased length of moment arm provides more destabilizing torque due to camber thrust.

- Interaction between damping coefficient and spring stiffness-
  A spring-damper combination of low stiffness and high damping coefficient results in less road holding as compared to a combination with low stiffness and low damping coefficient.maximum road holding is observed in case of a combination of less damping factor and higher order of stiffness.
- Interaction between toe and spring stiffness-
  At a slight amount of toe, high degree of road holding is observed, irrespective of the variation in stiffness; but, as toe increases, road holding ability also decreases. This could be attributed to the destabilization of the vehicle by excess self-aligning torque.Toe-in and spring stiffness both result in an unsettling ride. This interaction is perhaps the most detrimental to comfort in a car.
- Interaction between toe and damping coefficient-
  At less amount of toe-in, damping characteristics literally show no influence whatsoever on road holding. As toe in is increased, road holding decreases drastically with increase in damping coefficient even leaving the road at higher damping coefficient.

VI. Conclusion

This paper aimed at optimisation of camber angle for ride comfort and vehicle handling. A model was developed in ADAMS CAR software and the graphs were obtained for forces in upper control arm , lower control arm and strut forces. Calculations done for similar forces were studied and both the graphs and calculated values were found to be in reasonable agreement. This lead us to conclude that the overall forces acting on suspension geometry was lowest at 0 camber angle as compared to -2 to 2 degrees forces. Therefore we can conclude that zero camber can help reduce forces induced in suspension geometry which helps in increasing ride comfort and vehicle handling. The fundamental suspension parameters like sprung stiffness, damping coefficient and sprung mass exert an inversely related influence on ride comfort and road holding respectively. However, steering geometry parameters like camber and toe render unforeseen and hitherto unexpected influences.

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