Design Analysis Of Four Link Type Suspension For An Automobile Vehicle Using Adams Software

Mr. Sunil R. Kewate
Asst. Prof. Mech. Dept
Govt. College of Engg. & Research, Awasari(Kh)
Sunilkewate@rediffmail.com

Mr Vivek R. Gandhewar
Asso. Prof . Mech Dept
J.D.I.E. T. Yavatmal(M.S.)
Vivek.gandhewar@rediffmail.com

Miss. Richa A. Khatod
Student, Mech. Dept.
Govt. College of Engg. & Research,
Awasari(Kh)

***Abstract*—** Today's industry demands the replacement that gives versatile, efficient, comfort and cost effective equipment while at the same time providing more flexibility along with significant savings through increased productivity. Also the interaction happened during the development of an activity include investigation of available methodologies, finding the drawbacks in the existing system, creation of new innovative ideas, checking the feasibility of ideas, gathering of relevant information, application of theoretical knowledge for designing of system, verification using computer oriented technologies, finally implementation of best solution gives us the opportunities to come true is the replacement of suspension system. Four link type suspension systems have been widely applied to vehicles, from the horse-drawn carriage with flexible leaf springs fixed in the four corners, to the modern automobile with complex control algorithms. In this paper, by using ADAMS/Car software, it can be included that how quickly creates assemblies of suspensions and full vehicles by defining vehicle subsystems, such as front and rear suspensions, steering gears, anti-roll bars, and bodies. Based on these subsystems on their corresponding standard ADAMS/Car templates and then analyzed them to understand their performance and behavior and the software enables one to work faster and smarter, letting one have more time to study and understand how design changes affect vehicle performance. Also this software explores the performance of one's design and refine one's design before building and testing a physical prototype and analyzes design changes much faster and at a lower cost than physical prototype testing would require.

Keywords- *Four link type suspensions, Spring Design, Vehicle subsystem, ADAMS/car Templates, Analysis etc.*

*****

I. INTRODUCTION

Suspension system plays an important role for comfortable ride passengers besides protecting chassis and other working parts from getting damaged due to road shocks. If in a vehicle both front &rear axles are rigidly fixed to the frame. While vehicle is moving on the road, the wheels will be thrown up and down due to the irregularities of road; as such there will be much strain on the components as well as the journey for the passengers in the vehicle will also be very uncomfortable. The frame as well body of vehicle is attached to the rear axle & front axle by springs. These springs damped road shocks transmitted to the body structure by the wheels. In this way the springs are the protecting units supported directly by the frame of vehicle. Therefore all the parts, which perform the function of protection, are collectively called as suspension system. These springs are generally of leaf springs, coil springs, torsion bar or any other type. The suspension system is essential for the automobile vehicle in order to prevent damage to the working parts, to provide riding comfort and safeguard the occupants from road shocks, to give stability to the vehicle in case of rolling, pitching, to provide ground clearance and bear torque and braking reactions and to isolate the structure of the vehicle from shock loading and vibrations. In this paper, it includes the designing steps such as the Acceptance Test Procedure (ATP) for Manufacturing of Helical Coil Spring and then visual inspected that no sharp edges are allowed and no other visual defects, which impair the functional aspects of the helical spring are present. The main focus of this paper work is given on design and analysis of four link type suspension system using ADAMS/ car software.

It explained the creating Template for Four Link Suspensions and getting the hard point form solid point. Also it introduces the creating vehicle sub systems of assemblies and based on these subsystems on their corresponding standard ADAMS/Car templates and then analyzed them to understand their performance and behavior and the software enables one to work faster and smarter, letting one have more time to study and understand how design changes affect vehicle performance.

II. LITERATURE REVIEW

"Four link suspension". In the literature, a number of studies exists dealing with the four link suspension.
Four link suspension system. A sample of the relevant literature is as follows
İbrahim Esat described a method for optimization of the motion characteristics of a Four link suspension system by using a genetic algorithm. The analysis considered only the kinematics of the system (Esat 1999).T.Yamanaka, H.Hoshino, K. Motoyama developed prototype of optimization system for typical Four link suspension system based on genetic algorithms. In this system, the suspension system was analyzed and evaluated by mechanical system simulation software ADAMS (Yamanaka, Hoshino and Motoyama 2000).Hazem Ali Attia presented dynamic modelling of the four link suspension system using the point-joint coordinate's

formulation. In his paper, the four link suspension system is replaced by an equivalent constrained system of 10 particles. Then the laws of particle dynamics are used to derive the equations of motion of the system Attia 2002.Jozef e**t** **-**One of the most commonly used types of independent rear suspension is the multi- link suspension. Compliance is incorporated in the suspension system either in the form of springs where they are used to provide compliance, but do not participate in the kinematics of the suspension, or in the form of leaf springs where they are used to provide compliance as well as partially or completely responsible for the kinematics of the suspension. One of them is the multi-link rear suspension which uses springs for its energy storage mechanism. Jozef et,al (23) discusses one such very commonly used multi-link suspension where the multibody system comprises of rigid links (wheel carrier, kinematic links) and compliant elements (springs), linked to each other by kinematic joint.

III. DESIGN AND ANALYSIS

A. Design of four link suspension system

The four link type suspension system includes helical coil springs and linkages. In design, the material selection is first part and then selects the input dimension as shown in table 1. So there are various tubing materials like A-53 pipe, Chromium- molybdenum steel and aluminum. From the design point of view and its characteristics, the Chromium-Molybdenum steel is selected because, it is high tensile strength 620-650 MPa in the normalized condition and malleability. It is also easily welded and is considerably stronger and more durable than standard steel.

Table 1. Input Dimensions

Sr.No.	Description	Symbol	Value
1	Rear axle weight	W	3102.5 Kg
2	Length of link	L	1150mm
3	Outside diameter	OD	63.5mm
4	Thickness	Th	12.7mm
5	Inside Diameter	ID	38.1mm

The first step in building a four-link consist of taking dimensions from Workshop Maintenance manual for "stallion 4x4 mark ɪɪɪ" and constructing diagram in AutoCAD as shown in fig 1. By using this figured out, the axle centerline points on the bottom half were located, where the frame should sit above the axle. The center of gravity of the sprung weight was located

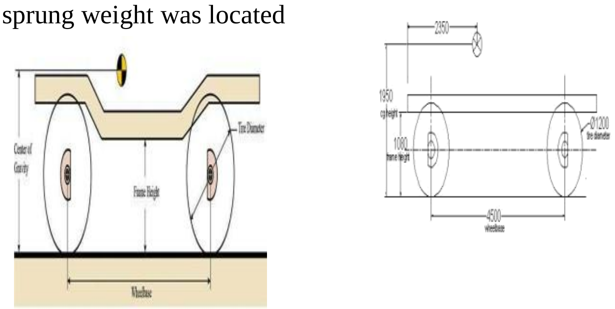


Fig 1. Diagram for basic chassis dimensions

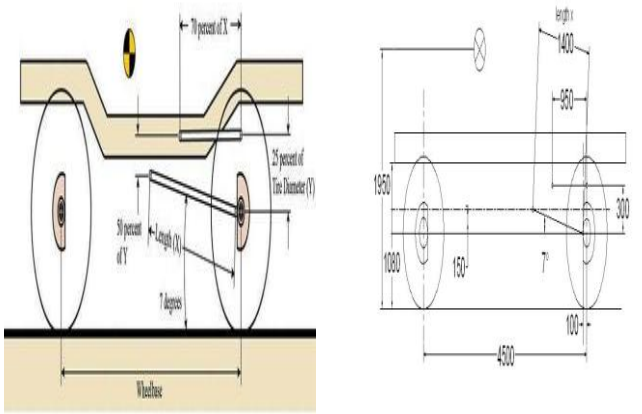


Fig 2. Locating upper link and lower link

The second step in the process is marking a horizontal line at a distance of 50% of tire diameter (y). Now, considering lower link axle as center, an arc is drawn at a distance of lower link length. The intersection point of horizontal line and arc is called as lower link frame. Now the lower link is constructed between lower link axle and lower link frame. Now draw a horizontal upper link of length which is 70% of lower link length. It is drawn from the point upper link axle.

Now the ends of the links are projected in top view from the side view as shown in fig 2

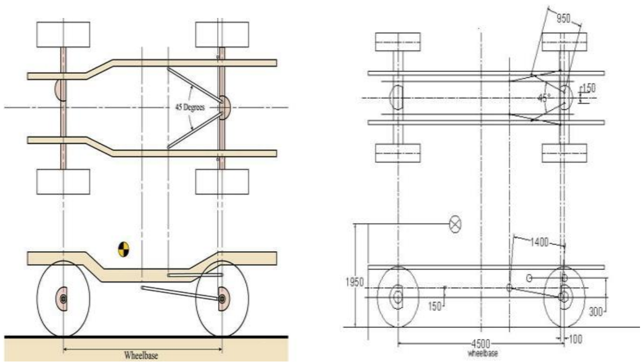


Fig 3. Locating angle between two upper links

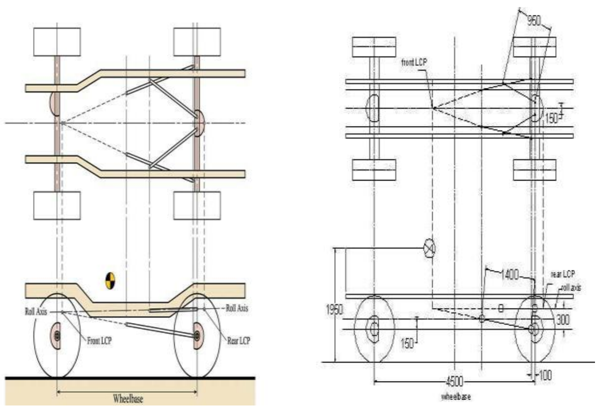


Fig 4. Locating the roll axis

Locating the upper links first, the angle between two upper links is 45 degree. This angle is locates axle, laterally or side to side as shown in fig 3.

A vertical line is projected down from the LCPs to the side view drawing as shown in fig 4. The links are extended so as to get an intersection point. This intersection point is joined with the LCPs. Now this line is called as roll axis. Extend line from upper link frame and lower link frame. These lines meet at a point called instant center.**.**Load calculations of suspension system- The inputs of load calculation for the suspension system as given in table 2 and the forces in three directions on wheels as shown in fig 5

Table 2. Inputs of load calculation

Sr. No.	Description	Symbol	Value
1	Total vehicle weight	W	116.54KN
2	Front axle weight	F1	56KN
3	Rare axle weight	F2	61KN
4	Tire-Road Coefficient of friction	μ	1.5
5	Wheelbase length	l	4500mm
6	Average longitudinal acceleration (deceleration)	ā	2.5m/sec2
7	Vehicle mass	m	1200 Kg
8	Centre of gravityheight	h_{cg}	1950mm
9	Acceleration of gravity	g	9.81m/sec2
10	Distance between breaking force and lower ball joint	a	331mm
11	Distance between two ball joint	h	416mm
12	Scrub radius	rs	159mm
13	Lower ball joint to projected steering axle (PSA)	c	77mm
14	Upper ball joint to projected steering axle (PSA)	b	132mm
15	Steering arm length	d	300mm
16	Lower control inclination	α	9°
17	Steering axis inclination	Ø	5°
18	Vertical distance between lower ball joint to steering arm	e	282mm

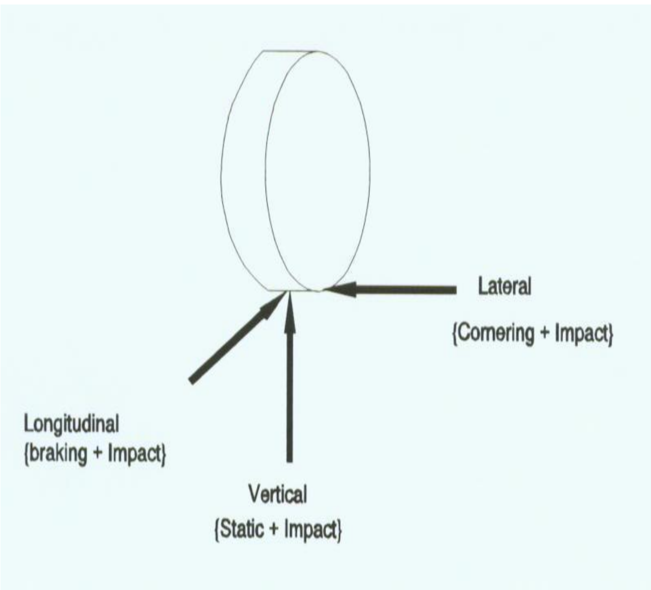


Fig 5. Wheel loads and directions

a) Front Axle Breaking Force (F_B) per Wheel-

FB= μ/2[Static+ dynamic load] = μ/2[W* bcg/l + m* ā *hcg/l] = μ/2 W [bcg/l +ā/g hcg/l]

We have to find the term b_{cg}, Consider a simply supported beam, where force F= 117KN which acts at a distance X from point A- $R_A = F_2 = 61KN$, $R_B = F_1 = 56KN$

Taking moment at point A- ∑mA= 0,117 * X - 61 * 4500 = 0, X= 2346.15mm.

b_{cg} = 4500 – X = 2154.84mm

Now breaking force FB can be calculated as FB = 51KN

b) Vertical Force (F_V)-

F_V = 3/2 [W *bcg/l + m* ā *hcg/l]=3/2 W [bcg *g + ā *hcg / gl] = 100 KN

c) Lateral Force (F_L)-

F_L = W [bcg* g + ā* hcg / gl] = 68.92 KN

d) Force on Upper Ball Joint (F_{US})-

Taking moment at point b**,** $\Sigma M_b = 0$, $F_{us}* h = F_B* a$, $F_{us} = F_B *a/h$ = 39.08KN

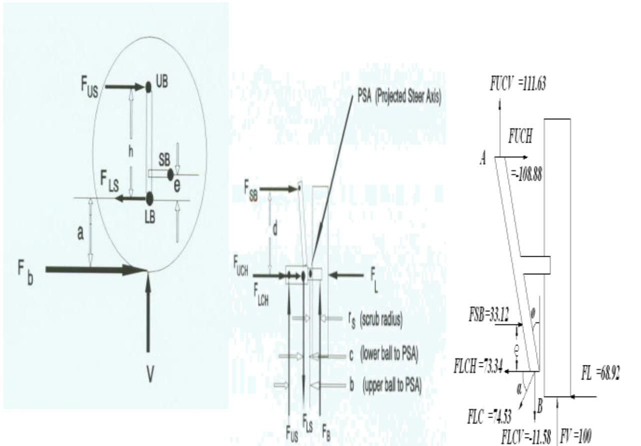


Fig 6. Forces on Side view and Top View front wheel (short long arm) SLA front suspension

e) Force on Lower Ball Joint (F_{LS})-

Resolving all the force horizontal $\Sigma F_x = 0$, $F_{US} - F_{LS} + F_B = 0$, $F_{LS} = F_{US} + F_B$, $F_{LS} = F_B$ [a/h +l] = 89.82 KN

f) Force on Steering Arm. (F_{SB}) - Taking moment at point Project steer axis (PSA), Σ M PSA =0

$F_{SB}* d + F_{US}* b - F_{LS} *C - F_B *r_s = 0$, F_{SB} = l/ d [F_{LS}* C + F_B* r_s – F_{US}* b]

F_{SB} = F_B /d [rs + C – a/h (b-c)] = 32.05KN

g) Forces on Lower Control Arm (F_{LC})

Taking moment at point A Σ M_{UA} =0

F_{LCV}* h* Tanφ + F_{LCH}* h + F_{SB} (h-e) + F_L (a+h) –F_V (rs +C) =0, F_{LCV} = F $_{LC}$ Sin α, F_{LSH} =F_{LC} cos α

F_{LC} = F_v (rs +C) – Fs* b (b-e) – F L (a+h) / sinα* tanφ + cosα* h = -74.23KN

h) Forces on Lower Control Arm Vertical (F_{LCV}) and Arm Horizontal (F_{LCH})

F_{LCV} = FLC sinα = -11.58KN, F $_{LCH}$ = F $_{LC}$ cos α = 73.34 KN

j) Forces on Upper Control Arm Horizontal (F_{UCH}) and Arm Vertical (F_{UCV})

$F_{UCH} = F_{LCH} + F_{SB} - FL$ = -108.88KN , $F_{UCV} = - F_V + F_{LC} \sin\alpha$ = 111.63 KN

Summary of load calculation and design calculation is as shown in table 3. The following parameters are calculated and selected shown in tabular form in table 4. and specification for Helical Coil Spring: the detail specification of spring is as shown in Table 5.

Material- IS GRADE 51CrMoV4 as per IS 3195:1992,Modulus of Rigidity-78500 N/mm², Density-7850 Kg/m³

 ISSN: 2321-8169
089– 094

Table 3. Load calculation

Sr. No.	Description	Symbol	Value
1	Outside diameter	OD	63.5 mm
2	Thickness	Th	12.7 mm
3	Inside diameter	ID	38.1 mm
4	Weight	W	31025 kg
5	Length	L	1150 mm
6	Moment of inertia	M.I.	804887.5 mm^4
7	Section modulus	Z	21868.54 mm^3
8	Stress	σ	400.128 N/mm^2

Table 4. Design Calculation

SR.NO	Description	Symbol	Value
1	Front axle Breaking force per wheel	F_{SB}	51.59
2	Vertical Force	F_V	103.38
3	Lateral Force	F_L	68.92
4	Force on upper ball joint	F_{US}	41.13
5	Force on lower ball joint	F_{LS}	92.82
6	Force on steering arm	F_{SB}	33.12
7	Force on lower control arm	F_{LC}	-74.23
8	Force on lower control arm vertical	F_{LCV}	-11.58
9	Force on lower control arm horizontal	F_{LCH}	73.34
10	Force on upper control arm horizontal	F_{UCH}	-108.88
11	Force on upper control arm vertical	F_{UCV}	111.63

Table 5. Specification of spring

SR NO.			
1	Wire dia. of spring	32	21
2	Mean dia. of spring	188	122
3	Inner dia. of sprig	156	101
4	Outer dia. of spring	220	143
5	No. of active coils	7.16	10.1
6	Total no. of coils end to end	8.65	11.6
7	No. of dead coils	1.5(each side 0.75)	1.5(each side 0.75)
8	Free length of spring	505	505
9	Solid length of spring	229.12	212.1
10	Pitch of the coil	62	46
11	Stiffness	213.05	107.27
12	Wind direction	Right hand	Left hand

B. Analysis

Creating Template for Four Link Suspensions-For creating the template hard points were required. The hard points were taken from the solid model created using CAD software Solidworks. The origin of the solid model is the center of differential. But all the dimensions with respect front origin were required. The following process is adopted for getting the hard points. Getting the hard point form solid point- Next to get the hard point from solid model, the tool "measure" in Solid works was used. After new hard points were obtained by shifting the origin from "chassis" to the "differential" center as shown in table 4

Table 6. Hard points , new hard points from Solid works

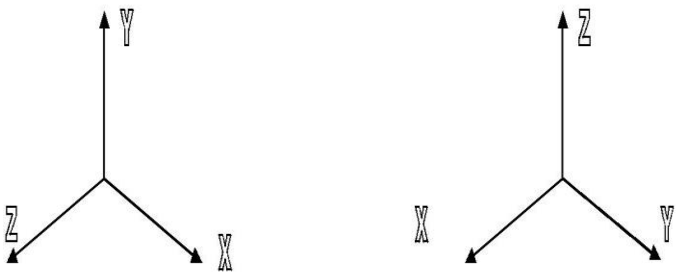
HARD POINT NAME	LOCATION OF POINT	CO ORDINATE X	CO ORDINATE Y	CO ORDINATE Z
Lower Link Frame	Left/Right	597.5	-180.1	3164
Upper Link Frame	Left/Right	676	-26	3652.5
Lower Link Axle	Left/Right	767.5	-321	4292.5
Upper Link Axle	Left/Right	342.5	-26	4457.5
Lower Damper	Left/Right	635	-295.5	4572.5
Upper Damper	Left/Right	697.2	210.698	4572.5
Spring Seat Lower	Left/Right	767.5	-245	4457.5
Upper	Left/Right	767.5	155	4457.5
Wheel Center	Left/Right	267.5	-320	4457.5

HARD POINT NAME	LOCATION OF POINT	CO ORDINATE X	CO ORDINATE Y	CO ORDINATE Z
Lower Link Frame	Left/Right	330	59.9	3206.05
Upper Link Frame	Left/Right	408.5	214	3694.55
Lower Link Axle	Left/Right	500	-81	4334.55
Upper Link Axle	Left/Right	75	214	4499.55
Lower Damper	Left/Right	367.5	-55.5	4614.55
Spring Seat Lower	Left/Right	500	-5	4499.55
Spring Seat Upper	Left/Right	500	395	4499.55
Wheel Center	Left/Right	0	-80	4499.55

Table 7. Hard Point Form Adams (Car)

HARD POINT NAME	LOCATION OF POINT	CO ORDINATE X	CO ORDINATE Y	CO ORDINATE Z
Lower Link Frame	Left/Right	3206.05	-330	59.9
Upper Link Frame	Left/Right	3694.55	-408.5	214
Lower Link Axle	Left/Right	4334.55	-500	-81
Upper Link Axle	Left/Right	4499.55	-75	214
Lower Damper	Left/Right	4614.55	-367.5	-55.5
Upper Damper	Left/Right	4614.55	-429.7	450.698
Spring Seat	Left/Right	4499.55	-500	-5
Wheel Center	Left/Right	4499.55	0	-80

ADAMS hard points for analysis: Adams (car) axis system is different from Solidworks as shown in Table 6.



Creating the Rear Suspension Template and modify the spring- Create a template and modify spring Parameter of Rear Suspension and create sub system assemblies as shown in window dialog box Menu below in Fig 7.

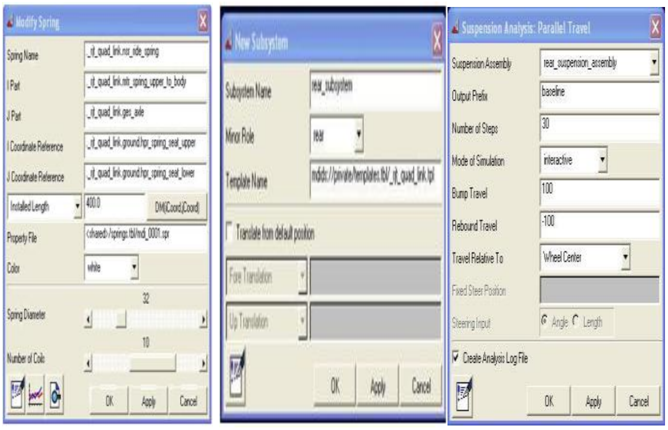


Fig 7. Modify Spring Parameter, New Subsystem and Suspension Analysis in ADAMS (Car) Window

The ADAMS/Car main window of new suspension assembly and hard point modification in tabular form appears as shown in Fig 8.

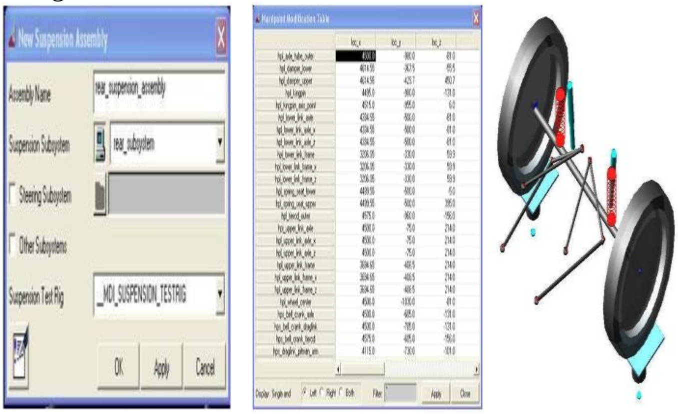


Fig 8. New Suspension Assembly and Hard point modify table Open Dialog Box In ADAMS (Car) Window

Setting of the Suspension Parameter in ADAMs/car Software-Form the simulate menu, point to suspension analysis and then select set suspension parameters and fill the required information of suspension system. It appears set suspension parameter window as shown in fig 9.

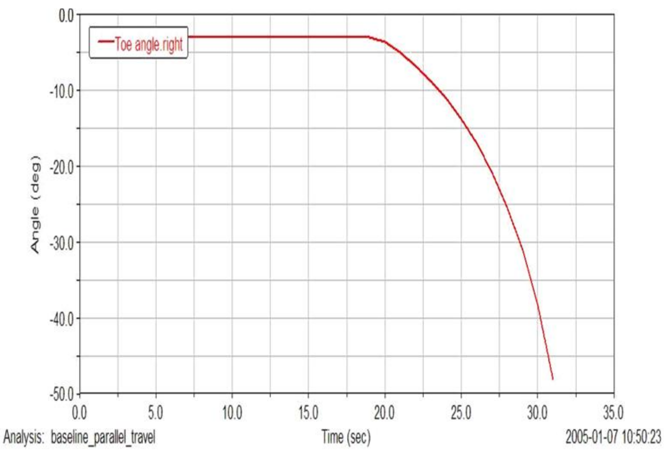


Fig 9. Set suspension parameter

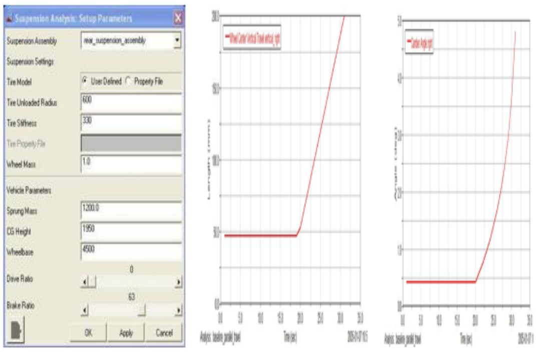


Fig 09. Graph of wheel travel Vs time**,** camber angleVs wheel travel,Toe angle Vs time

Post Processing-Results obtained are plotted in the graph of wheel travel Vs time and camber angle Vs wheel travel is obtained on the window, as shown in fig 10

IV. CONCLUSION

High mobility is the prime requirement in cross country terrain for any defense/ off vehicle. The technical parameter considered for improving the mobility of vehicle was wheel travel. Four link suspensions for rear axle of the heavy truck were designed. A design calculation for estimation of length and cross section is also undertaken as part of analysis. Different design of coil springs are evolved and studied such as twin coil spring, single coil spring and nested coil spring design for the suspension system. Due to design constraint and analysis result in ADAMS/ car software, the nested spring is chosen for the suspension. Therefore, the nested coil spring is recommended and suggested for the development of four link suspension system using ADAMS/ car software. These results are compared to ADAMS/car software and CAD software Solidworks, the findings include that results are appropriately acceptable. Rear wheel four link dependent suspensions for heavy truck is taken for load calculations and based on free body diagram of four link suspensions were carried out.

ACKNOWLEDGMENT

"Completing a task is never a one man‟s effort. Several prominent people in production, academics, and administrative field have helped in Design analysis four link type suspensions for an automobile vehicle using ADAMS software– a practical problem of industry for this present research work. Their collective support has led in successful design and development of this work. To name them all is impossible."

I am thankful to colleagues, at, Government College of Engineering, Awasari, Pune, and various other institutions for cooperation provided by them. Special thanks to the Principal and teaching staff of GCOEAR, Awasari, and M/S Kedar engineers, Pune sponsored of this work for needful support and encouragement for making successful.

REFERENCES

[1] Timoney, E.P., Timoney, S.S., Timoney, S.G., "Heavy vehicle independent suspension", Proceedings of the IMechE, "Advanced suspensions", C434/88, 1988-9, p 125-133.

ISSN: 2321-8169
089– 094

[2] Prior, Gary M., "The use of multi-body systems analysis in the design and analysis of vehicle suspension systems", SAE 921463, 1992.
[3] Dynamic Analysis of Four link Suspension by Duygu GÜLER inJuly 2006
[4] Kami, Y., Minikawa, M., "four link suspension for Honda Prelude", SAE 841186,
[5] [5] Murakami, T., Uno, T., Iwasaki, H., Naguchi, H., "Development of a new multi-link front suspension", SAE 890179, 1989.
[6] Shim, T and Velusamy, P. C., Suspension Design and Dynamic Analysis of a Lightweight Vehicle, Int. J. Vehicle Design, Vol. 43, Nos 1-4, 2007.
[7] Gillespie, T. D., Fundamentals of Vehicle Dynamics, SAE, 1992.