Four Link Suspension For Heavy Vehicles (Replacing Leaf Spring)

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ABSTRACT

This paper presents the analysis of four link suspension by using the hardpoints. In current scenario it is necessary to look for a better suspension at the rear. Four link Suspension can be applicable for rear suspension for heavy vehicles. In general a vehicle is provided with leaf spring at the rear wheel where due to dependent suspension system the cause of accident increases. To avoid this failure of vehicle it is necessary that dependent system should be modified or replaced with any other relevant system. For this purpose, another system which may be incorporated is four link suspension system.

Keyword: - *Suspension, spring, four link*

1. INTRODUCTION.

The automobile frame and body are mounted on the axle not directly but through some form of springs and shock absorbers. This is done to damp road shocks transmitted to the frame by the wheels as they roll over the road. All these parts are collectively called a suspension system. A good suspension design provides stability and control over the suspension and handling of a vehicle. A conventional suspension should be “soft” to insulate against road shocks and “hard” to sustain load. Therefore, good suspension design is an need. Today, nearly all passenger cars and light trucks use dependent front suspensions, because it gives resistance to vibrations better. One of the commonly used dependent front suspension system is referred as “Four link suspension”.

2. LITERATURE REVIEW

İbrahim Esat described a method for optimization of the motion characteristics of a Four link suspension system of a genetic algorithm. This analysis considers only the kinematics of the system (Esat 1999).
T.Yamanaka, H.Hoshino, K. Motoyama developed prototype based on genetic algorithms optimization system for typical Four link suspension system can be evaluted. 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 coordinates formulation. In his paper, the four link suspension system is replaced by an equivalent constrained system of 10 particles. After this particle dynamics law are used to derive the equations of motion of the system Attia 2002).
Jozef et One of the most commonly used types of independent rear suspension is the multi- link suspension. Compliance is involved 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 they are 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. The multi-link rear suspension which uses springs for its energy storage mechanism. Jozef et,al 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.
Estill & Associates P/L , provides Configurations of Operational Stability and Performance of four link Suspensions on Various Vehicle. (Estill & Associates P/L, September 2000)
Roaduser International P/L (Investigation into the Specification of Heavy Trucks and Consequent Effects on Truck Dynamics and Drivers: Final Report. (Report prepared for DoTRS by Roaduser International P/L) (2000)

3. Basic Terminology

Sprung Weight

The sprung weight typically includes the weight which is suspended by spring i.e. body weight, frame, the other integral components, passengers, and cargo, but it does not considers the mass of the components suspended below the suspension components

Unsprung weight

The Unsprung weight includes the mass of components such as the wheel axles, wheel bearings, tires, and a portion of the weight of drive shafts, springs, shock absorbers, and suspension links.

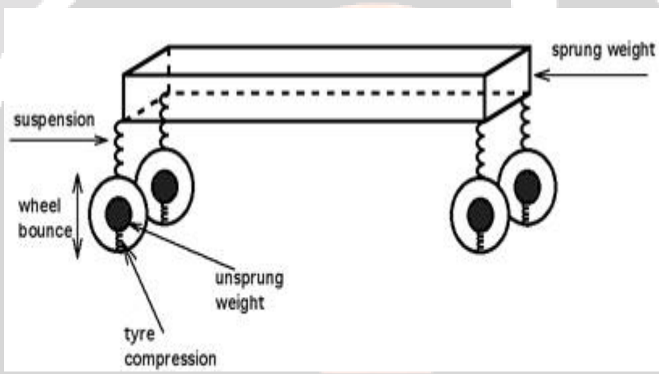


Fig -1: Sprung &Unsprung Weight

Camber

It is the tilt of the wheel from the vertical Or the angle between the centre line of tyre and vertical line when viewed from front of vehicle is known as camber.

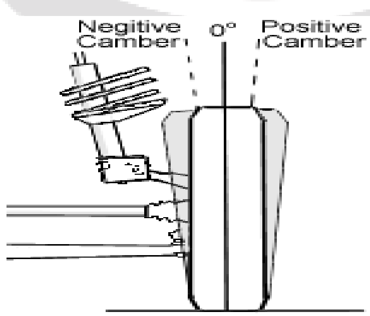


Fig -2: Camber

Caster

The angle between the king pin centre line (or steering axis) and the vertical in the plane of the wheel is called caster angle. If the king pin centre line meets the ground at a point ahead of the vertical wheel centre line it is called positive caster while if it is behind the vertical wheel centre it is called negative caster.

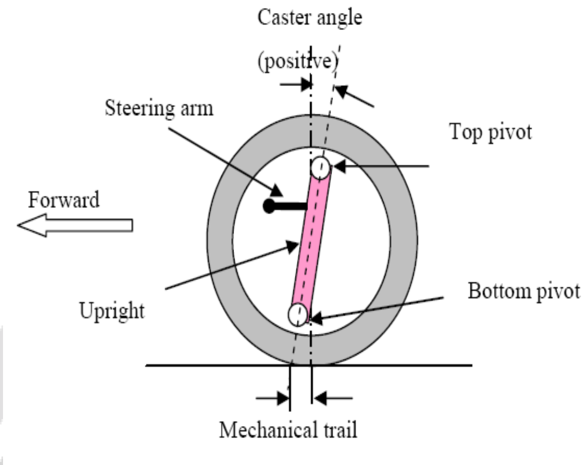


Fig -3: Caster

What is four-link?

A four-link suspension uses links to locate the axle from moving, side to side and front to back, while allowing it to travel up and down . The well designed and tested four-link will provide a superior translation of power to the ground and higher ride quality than a leaf-sprung suspension. Four links are required to provide longitudinal and lateral control of the wheels and reacting brake torque. The use of linkages provides flexibility for the designer to achieve the wheel motions desired.

Four link rear suspensions

In case of four link suspensions with a solid axle, the lateral force acting on the Wheel, in the top view must react as tension and compression forces in the control arms.

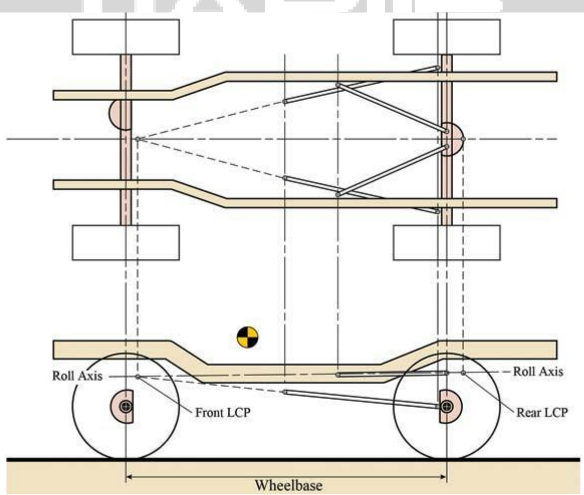


Fig-4 : Position of four link

The design of four link involves mounting of all the links as per the suitable position. In this system it consist of upper link and lower link. The upper links connects from top of the rear axle to the frames and the lower links connect from outer end of axle tube to the frame. The initial important factor in this system is the tire diameter. The upper link can be located at 25% of the tire diameter. The tire diameter can be designated as A, the upper link location will be 0.25A and this distance is designated as Y. The lower links should be provided with 7 to 10 degree angle when looking from the front. The inward angle between the upper link should be 45 degree when looking from the top. The length of lower frames can be designated as X. The length of upper link should be 70% of the lower links i.e. 0.7X. Distance between the upper and lower link should be 0.25Y .

Material Selection

There are various tubing materials like A-53 pipe, Chromium- molybdenum steel and aluminum. In the table given below number indicates selection of the material and XX indicates the percentage of carbon.

Table -1: -Material List

	Carbon Steels
10xx	Plain Carbon (Mn 1.00% max)
11xx	Resulfurized
12xx	Resulfurized and Rephosphorized
15xx	Plain Carbon (Mn 1.00% to 1.65%)
	Manganese Steels
13xx	Mn 1.75%
	Nickel Steels
23xx	Ni 3.50%
25xx	Ni 5.00%
	Nickel-Chromium Steels
31xx	Ni 1.25%, Cr 0.65% or 0.80%
32xx	Ni 1.25%, Cr 1.07%
33xx	Ni 3.50%, Cr 1.50% or 1.57%
34xx	Ni 3.00%, Cr 0.77%
	Molybdenum Steels
40xx	Mo 0.20% or 0.25%
44xx	Mo 0.40% or 0.52%
	Chromium-Molybdenum
41xx	**Cr 0.50% or 0.80% or 0.95%, Mo**
	Nickel-Chromium-Molybdenum Steels
43xx	Ni 1.82%, Cr 0.50% or 0.80%, Mo 0.25%

Why

From the above material list 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

Material Selection for spring

The selection of material for the spring wire depends upon the following factors:

- The load acting on the spring

- The range of stress through which the spring operates
- The limitations on mass and volume of spring

There are number of materials available for spring in which alloy steel wires are most suitable for the application of higher stress and impact strength. Alloy steel wires are superior than carbon steel wires, but the coat of alloy steel wire is greater. The suitable design can be done by using the equations given below. The factor of safety on design of springs is usually 1.5 or less.

IS GRADE 51CrMoV4 as per IS 3195:1992

Table -2: -Percentage Composition

CONSTITUENT	PERCENTAGE
C	**0.48 to 0.56**
Si	**0.15 to 0.40**
Mn	**0.7 to 1.10**
Cr	**0.9 to 1.2**
Mo	**0.15 to0.25**
V	**0.08 to 0.15**
S	**0.030 max**
P	**0.030 max**

EQUATIONS

a) Wire Diameter of Outer Spring (d_1) = $\frac{D_{01}}{(C+1)}$

b) Mean Diameter of Outer Spring (D_1) = $D_{01} - d_1$

c) Inner Diameter of Outer Spring (D_{i1}) = $D_1 - d_1$

d) Wire Diameter of Inner Spring (d_2) = $Zd_1 \frac{(C-1)}{(C+1)}$

e) Mean Diameter of Inner Spring (D_2) = $C\ d_2$

f) Outer Diameter of Inner Spring (D_{02}) = $D_2 + d_2$

g) Inner Diameter of Inner Spring (D_{i2}) = $D_2 - d_2$

h) No. of Turns on Outer Spring (N_1) = $\frac{2GD_{01}}{8KC^3}\left[\frac{(C^2+1)}{(C+1)^3}\right]$

i) Total no. of Coils in Outer Spring (N_1') = $N_1 + 1.5$

j) No. of Turns on Inner Spring (N_2) = $N_1 \left[\frac{(C+1)}{(C-1)}\right]$

k) Total no. of Coils in Inner Spring (N_2') = $N_2 + 1.5$ …………… (Assuming Squard & Ground End)

l) Solid Length of Outer Spring (L_{s1}) = $N_1 d_1$

m) Solid Length of Inner Spring (L_{s2}) = $N_2 d_2$

n) Spring Stiffness of the Outer Spring (K_1) = $\frac{GD_{01}}{8C^3 N_1 (c+1)}$

o) Spring Stiffness of the Inner Spring (K_2) = $K_1\left[\frac{c-1}{c+1}\right]^2$

p) **)** Force on Outer Spring (F_1) = $\frac{FK_1}{K}$

q) Force on Inner Spring (F_2) = $F - F_1$

r) Shear stress on Outer Spring (S_1) = Shear stress on Inner Spring (S_2) = $\frac{8CF_1(C+1)^2}{\pi D_{01}^2}$

s) Life Cycle (n) :$K_E = C_E * n^{-y}$

Analysis Using multi body dynamics simulation software

By getting the hardpoints from the modeling software for x, y and z co-ordinates one can define the positions of hardpoints for multi body dynamics simulation. MSC ADAMS is a software which provides multi body simulation by using hardpoints. Below figure shows the position of four links and suspension.

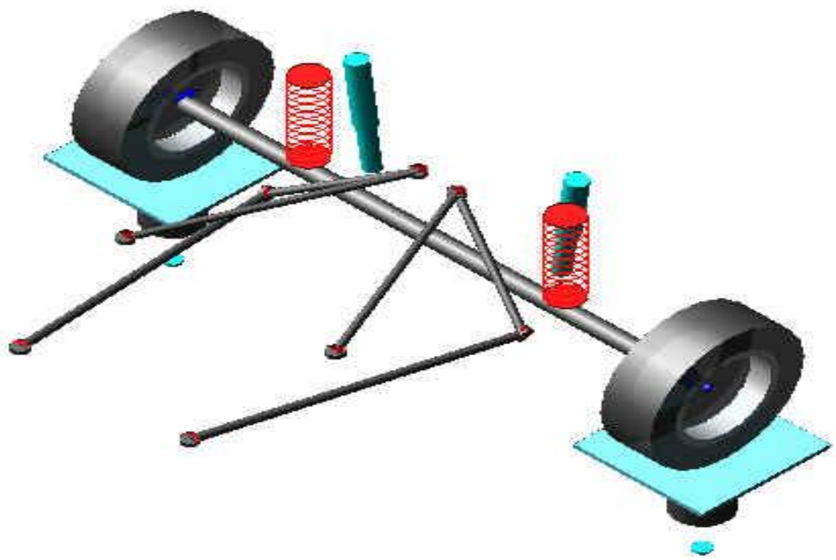
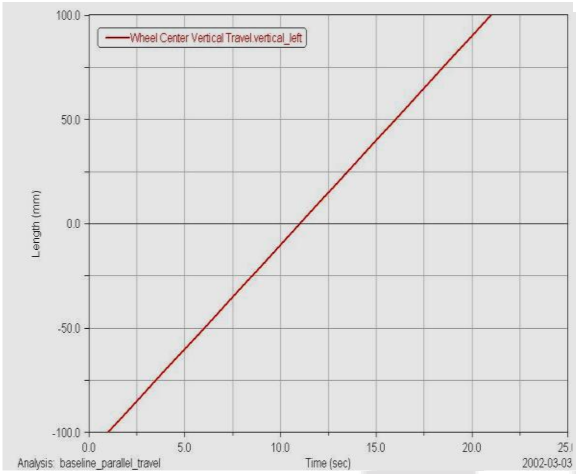
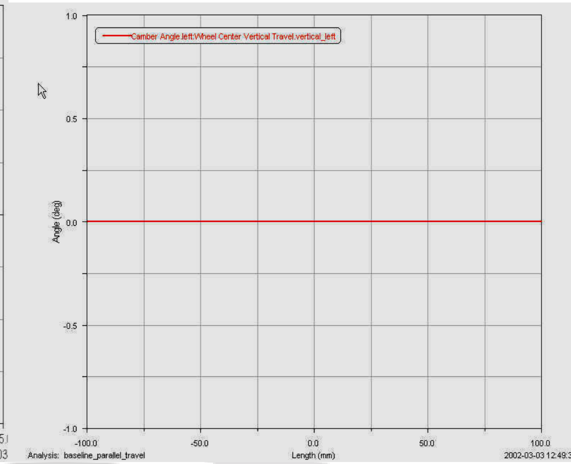


Fig-5 : Analysis of system using hardpoint

The analysis using the input dimension has been carried out on the system and the graph has plotted. In which wheel travel of 100 from mid point is provided which is shown in graph 1. The graph shows the uniform travel of wheel for the analysis. Graph 2 shows that there is nop change of camber angle for the given wheel travel.





Graph-1: Wheel Travel Vs Time **Graph-2:** Camber Angle Vs Wheel Travel

4. CONCLUSIONS

A multibody simulation is used for the analysis. By providing the inputs and design calculation a prototype on software is generated in which parallel wheel travel, right wheel travel, left wheel travel and opposite wheel travel was carried out. Extreme position of wheel travel was considered and compared to the objectives.

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