SUSPENSION SYSTEM FOR AN ALL TERRAIN VEHICLE

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ABSTRACT-*The main objective of this paper is to explain the design methodology which has been opted for the suspension system of an All Terrain Vehicle .Double wishbone independent suspension system is designed for the front half and trailing arm independent suspension is designed for the rear half. All the calculations which are required have been discussed. The analysis of the suspension system is also done by using simulation software Lotus shark.*

I.INTRODUCTION

There are different types of suspension system which can be used for a vehicle depending upon our need. Basically suspension can be classified into 2 types:

Independent

suspension Dependent

suspension

1) **Independent Suspension :** The term independent indicates that suspension system for both the wheels are independent of one another i.e., whenever a bump or droop comes across ,both the wheels behave independently. To put it up in simple terms the wheel travel (movement of wheel up and down in vertical direction) can be seen only on that side where the wheel undergoes bump or droop. Where as the other wheel maintains contact with the road.

Examples of independent suspension :

i) Double wishbone

ii) Mc person struct

iii) Swing arm

2) **Dependent Suspension :** In this type suspension if one wheel undergoes a wheel travel due to bump or droop the opposite wheel also undergoes the wheel travel, Unlike the independent suspension.

Example of dependent suspension :

i) leaf spring

ii) live axle

For an all terrain vehicle where the vehicle is made to run at different uneven terrains it is always better to opt for independent suspension system rather than dependent suspension. Of all the independent suspension systems available by studying the merits and demerits of each and every type, double wishbone and trailing arm suspension have been preferred for front and rear respectively.

The main functions of the suspension system in vehicle are:

i) To maintain traction between the tires and ground

II. CALCULATIONS

Total sprung mass: The entire mass that acts upon the wheels of the vehicle is considered as sprung mass i.e weight of the roll cage ,driver, engine, cvt, steering wheel, steering rack, braking. The lower the sprung mass is the better the performance of the vehicle.

Sprung mass:175 kgs

Total unsprung mass: The mass excluding the sprung mass is considered as unsprung mass i,e weight of the wheels, uprights, knuckles, a arms, Hubs, shock absorbers, trailing arms.

Unsprung mass: 65 kgs

Total weight: sprung mass + unsprung mass gives the total weight of the vehicle Total weight:175 +65 = 240kgs

Kerb weight: The weight of the vehicle excluding the driver's weight (Also known as curb weight)

Kerb weight : 240 – 60 = 180kgs

(Drivers weight is considered as 60kgs)

Front track width: Front Track width is the distance from tire centre to the other tire center. There is no specific formulation in deciding the track width of the vehicle but we need to consider certain basics like.

1) up to what value the rules will allow ?
2) what is the predominant track type the on which vehicle is to be run?
3) Are low speed tight circuits are of concerns ?
4) Is top speed thus top frontal area is important ?

Front track width: 52''inches

Rear track width: selection criteria for rear track width depend upon the same considerations as of front. However, we preferred the rear track width to be slightly greater than front for more stability of the vehicle

Rear track width: 53''inches

Static Ride height: static ride height is also said to be ground clearance. It is nothing but the distance between the ground to the chassis lowest point . It is always desirable to maintain a ride height at a moderate height which is not too high and not too low because if the ride height is low the vehicle may get hit at the bottom during getting over a bump and if the ride height is very high the height of COG increase which is also not a desirable scenario. So by benchmarking the ride heights of different commercial ATV's the ride height for our vehicle is determined as

Static ride height :12''inches

Tire diameter: The selection criteria for the diameter of the tire depends upon 2 factors

1) Vehicle torque
2) Braking disc and caliper that gets fitted inside rim

Tire diameter: 23"inch

Wheel travel: The movement of the wheel in vertical direction from top to bottom is known as wheel travel.

Table 1 The wheel travel of several vehicles is listed below

Type of car	Wheel travel
Off road	+/- 12
Passenger	+/- 4
Formula and sports cars	+/- 2 to 4
Indy type	+/- 0.5

Wheel travel rear: rear wheel travel is intentionally chosen to be less because if it is increased then there may arise a problem of slippage of split transmission shafts from the gear box which is connected to the rear wheel.
Wheel travel rear : 6 inches (4 inch bump,2 inch droop)

Spring travel: The maximum length that the spring can compress under the application of a certain load is known as spring travel.

Front spring travel: Fox Float 3 evol R shock absorbers are used for the front suspension whose maximum spring is restricted to 5.3 inches[3].

Front spring travel : 5.3 inches

Rear spring travel: for rear whose wheel travel is low when compared to front the spring Is also has been reduced and customized shock absorbers have been used whose spring travel is 3 inches.

Rear spring travel :3"inches

Installation ratio: the installation ratio is also known as motion ratio which is determined as spring travel/wheel travel.

Front: 5.3"/10"=0.53

Rear: 3"/6"=0.5

Ride frequency: it can be considered as the undamped frequency of the body moving up and down on the springs. usually the ride frequency can be determined once the static deflection has been estimated.

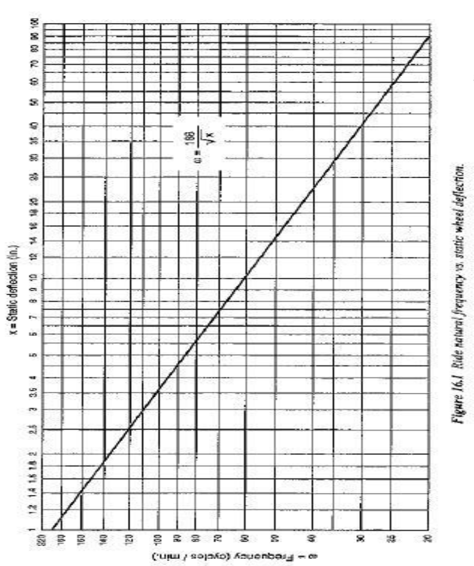

Figure 1 Graph represents relation between ride frequency and static deflection

Table 2 Ride frequency for few cars has been studied as

Type of car	Ride frequency
Sports car	70-90 cpm
Indy car	95-120 cpm
Passenger car	30-50 cpm

Higher the ride frequency, Stiffer the ride gets and vice versa. Usually ride Frequency of the rear is chosen more than that of the front in order to stabilize the Vehicle as soon as it hits a bump. When ever the vehicle comes across a bump the Front wheels undergoes vibration and after a time lapse the rear wheels vibrate. So if the ride frequency for rear is chosen more so that both the wheels will stabilize at same time

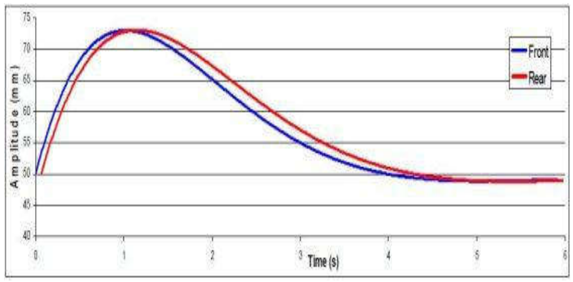

Figure 2 Normal case graph amplitude vs time [6]:

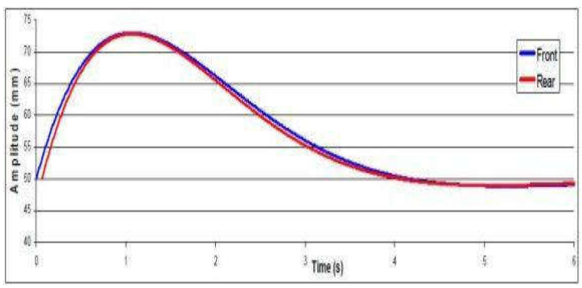

Figure 3 graph when 10% rear ride frequency is increased [7]:

The ride frequency for front : 2 hz and for rear: 2.5 hz

Spring constant: It is defined as force applied for unit deflection of spring. It is also defined as spring stiffness. The S.I. units for spring constant are N/mm or N/m. One of the key parameter of the suspension system. Generally spring constant(k) = force X displacement.

But in the automobiles undergo continuous fatigue loading, so due to this reason instead of normal formula we make use of ride frequency and obtain the spring constant value.

We know that

$$w = \sqrt{(k/m)}$$

where w = amplitude

k = spring constant

m= sprung mass

we also knew that

$$w = 2\pi f$$

where f = ride frequency

on equating both the equations we get

$k = 4\pi^2 m f^2$

units :N/m

using the above formula the spring constants for the front and rear suspension system are calculated . Quarter body analysis of the sprung mass is done so that sprung mass acting on each wheel is determined

The weight distribution according to the calculation is front : rear = 42.5:57.5

Front spring constant:

Entire sprung mass = 175 kgs

Front sprung mass = 175 x 0.425 = 74.375kgs

Multiplying the above mass with factor of safety : 74.375 x 1.5=111.5625 kgs

The load acting on each wheel at front : 111.5625/2 =55.8 kgs

$k = 4\pi^2 m f^2$

$k = 4 \times \pi^2 \times 55.8 \times 2^2$

k = 8811.58 N/m or 8.81N/mm

For front suspension FOX float 3 evol R pneumatic shock absorbers which have adjustable spring rate have been used.

Rear spring constant:

Entire sprung mass = 175 kgs

Rear sprung mass = 175 x 0.575 = 100.625 kgs

Multiplying the above mass with factor of safety : 100.625 x 1.5=150.93 kgs

The load acting on each wheel at front : 150.93/2 =75.46kgs

$k = 4\pi^2 m f^2$

$k = 4 \times \pi^2 \times 75.46 \times 2.5^2$

k = 18619 N/m or 18.619N/mm

For rear suspension customized shock absorbers have been used

Spring calculations :

$$k = Gd^4 / 8D^3N \text{ [8]}$$

Where,

k= spring constant

G= modulus of rigidity= 81370 N/mm^2

d= wire diameter

D= mean diameter

N= No. of active turns

C = D/d =spring index

Assuming C= 8 and N =12

$k = Gd^4 / 8D^3N$

$18.619 = 81370 \times d^4 / 8 \times (8 \times d)^3 x12$

d = 11.2 = 11mm approximately

D = C x d = 8 x 11 = 88mm

Wheel rate: vertical force per unit vertical displacement at the location along the spindle corresponding to the wheel center line measured relative to the chassis.

Wheel rate = spring rate x $(\text{motion ratio})^2$[9] Front wheel rate = 8.81 x (0.53) = 2.474 N/mm Rear wheel rate = 18.619 x $(0.5)^2$ =4.654 N/mm

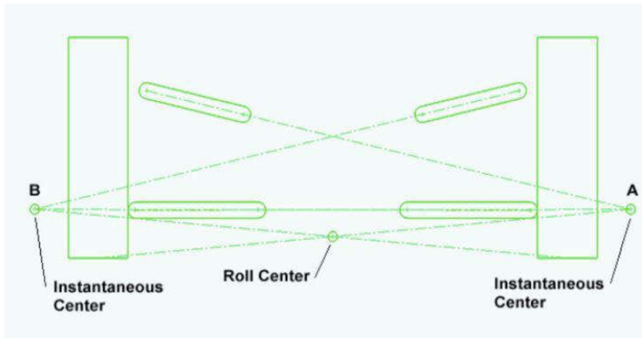

Figure 4 Roll center calculation

Front roll center height from ground: 167.39mm

Rear roll center height from ground : 177.818mm

III. LOTUS ANALYSIS

Lotus shark is a Market Leading Application For Suspension Modeling And Design. From The World -Leaders In Vehicle Ride And Handling; The Lotus Suspension Analysis Shark Module Is A Suspension Geometric And Kinematic Modeling Tool, With A User-Friendly Interface Which Makes It Easy To Apply Changes To Proposed Geometry And Instantaneously Assess Their Impact Through Graphical Results.

The virtual representation of the suspension system can be designed using this software all the mounting points can be changed according to our desire .once every input is given the simulation can be performed and various number of graphs (upto 18 different) can be obtained. The graphs include camber change vs wheel travel , wheel travel vs toe angle change , wheel travel vs Ackermann percentage , camber vs castor and so on. Once these graph are obtained they are given a detailed study and changes are made if they are required , if not the hard points (mounting points) are obtained which are used as reference during manufacturing phase.

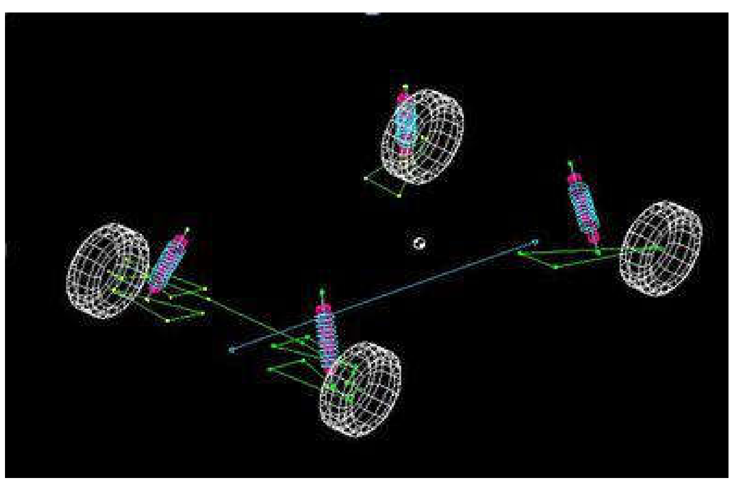

Figure 5 Simulation of the vehicle suspension in Lotus shark software:

Camber is defined as tilting of wheel inwards or outwards when viewed from the front view. If the top of the wheel is tilting inside and bottom of the wheel is tilted out , it is said to be negative camber . negative camber is Denoted by – sign. If the bottom of the wheel is tilted inside and the top is tilted inside , it is said to be positive camber denoted by + sign. If the wheel is perfectly straight without any tilt it is said to be zero camber.

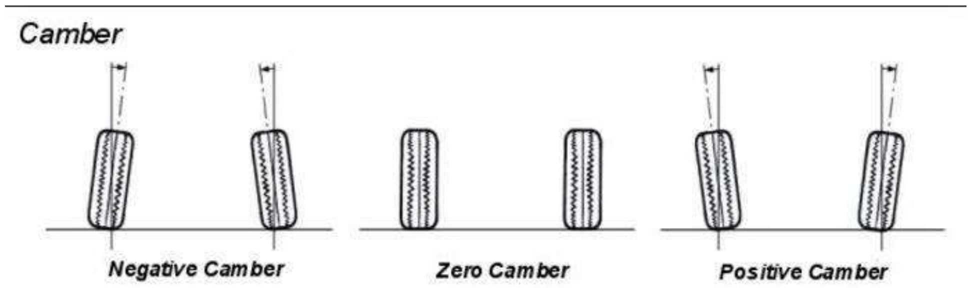

Figure 6 Pictorial Representation of camber

Zero camber is desirable always because it maintains a uniform contact patch with the ground. But however zero camber cannot be achieved due to the irregularities on the road.

The following graph is called as camber curve which discusses about camber change with wheel travel. It tells that the front wheels will undergo some camber which is appreciably small and there is no camber change for rear wheels.

IV. HARD POINT PICK UP

The Hard point pickup is nothing but the mounting points to of the suspension system for the chassis. After doing several iterations and lotus suspension stimulation software we decided the above hard points while deciding the we studied the following properties in three different types of motion

3 Dimensional bump 3

Dimensional steer

3 Dimensional roll

Inputs:

Front: 6” bump, 4” droop Rear: 4”bump, 2”droop

Roll: 2 degree

V. CONCLUSIONS

By using the above calculations and design methodology the suspension system for an all terrain vehicle i.e., double wish bone suspension for front and trailing arm for the rear has been fabricated successfully. The vehicle has been tested at different terrains in order to test it’s handling , traction and suspension efficiency and In all cases it has worked efficiently.

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