DESIGN AND ANALYSIS OF SUSPENSION SYSTEM OF AN OFF ROAD VEHICLE (ALL TERRAIN VEHICLE)

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Abstract—An ATV is the vehicle which is designed to move through all terrains. We are using this vehicle for various range of purposes such as military purpose, rescue purpose during natural calamities and also for forest inspections. Suspension system of this vehicle should be strong enough so that it will give better ride quality and maximum comfort to the driver. Double wishbone suspension system is selected and is designed in LSA (Lotus Suspension Analysis). After designing the hard points are received and using them A-arms are designed by using SOLIDWORKS and CATIA software and after that we selected the material to fabricate it but before fabrication we have analysed the various stresses acting upon it by ANSYS. We have also designed front and rear uprights and analysed it by using ANSYS. This project aims at selecting, analysing and fabricating a suspension system of ATV which will capable of handling at rough terrains.

Index Terms—Camber, Castor, Double Wishbone Suspension System, Roll Centre Height, Toe, Track width, Upright, Wheelbase.

I. INTRODUCTION

Suspension system is one of the major component of the vehicle which is used to have a maximum traction effort in between road and tyres and to provide maximum possible comfort to the driver. The contact between the road and tyres are maintained due to the load applied by the vehicle which acts through the tyres and suspension system. We have to design by keeping 2 aspects in our mind:

1. Uneven surface of roads.
2. Variations in the load.

Road irregularities includes the big hills and small uneven surfaces which may be termed as high frequency (hills) and low frequency (uneven surfaces). Variations in loads are due to various aspects like load during cornering, load during braking, load during acceleration. So to sustain in these cases we must have reliable suspension system which should be soft for giving comfort to the driver and hard for carrying uneven loads while travelling in the hills and mountains.

Suspension system reduces reaction force generated due to obstructions on the path of the vehicle. This reaction force’s magnitude is directly proportional to the unsprung mass of the vehicle. With higher sprung to unsprung weight ratio we can achieve more reduction of reaction force effecting both vehicle and the occupants and can also enhance vehicle control ability. So suspension system is mainly divided into 2 categories: Dependent Suspension System: Here in this suspension system the movement of one wheel depends upon another wheel. Independent Suspension System: Here in this suspension system the movement of one wheel does not depends upon another wheel. Here each wheel is independent of each other. So we have decided to choose Double Wishbone System as per our use of the vehicle. Double wishbone suspension system consist of two a-arms (upper wishbone and lower wishbone) usually of different length along with a spring and a damper. This type of suspension system provides negative camber at the time of ride and it has an excessive load bearing capacity. It also provides better stability and roll height.
II. DESIGN METHODOLOGY

Before designing the suspension system of vehicle we have concentrate upon some of the basic parameters of the vehicle required for it. So the basic parameters are:

1. Wheelbase: 60 inch.
2. Track Width: Front-54 inch, Rear-50 inch
3. Tire Radius: 12 inch
4. Tire Width: 8 inch
5. Sprung Mass: 180 kg
6. Unsprung Mass: 80 kg

So by using these parameters we started the process of designing the suspension system of the vehicle. We have selected the LSA (Lotus Suspension Analysis) software to design it.

2.1 LOTUS Suspension Analysis:
LOTUS suspension analysis tool is used for initial outline of the vehicle. 3D models can be created and modified in LOTUS Suspension Analysis (LSA). Using LSA Hard points are drawn and graphical and numerical values can be found out. This modelling approach allows user to make their own suspension models. The changes in camber angle, toe angle can be displayed graphically against motions like roll motion, bump motion, steering motion. Several parameters are considered to get the hard points of the suspension system like damping ratio, sprung and un-sprung weight, spring rate, camber angle, caster angle, roll centre, wheelbase, track width, toe angle, ground clearance.

So before designing in LSA we have design considerations:

- Kingpin and caster angle are kept in such a way that they can compensate each other’s camber gain, by providing there individual function.
- A positive kingpin angle is kept to help in steering the vehicle.
- Roll centre below CG to avoid jacking force.
- Front ride frequency is greater than rear.
- Roll axis inclined towards front to give understeer characteristic.
- Front double wishbone unequal parallel arm to have better traction during cornering.

![Fig1: Roll Axis is inclined toward the front.](image1)

![Fig2: Roll Centre below CG.](image2)

We have taken Damper to lower wishbone for the front suspension and damper to upper wishbone in rear suspension system. We have design by using these parameters and also by checking various properties such as roll motion, bump motion, steering motion. These properties are controlled by controlling the camber, caster, toe, kingpin angle etc. So after designing we get the results as:

Numerical value:

<table>
<thead>
<tr>
<th>Table1: Numerical results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Camber angle (Kerb Weight &amp; Suspension Travel)</strong></td>
</tr>
<tr>
<td>Caster angle</td>
</tr>
<tr>
<td>King pin angle</td>
</tr>
<tr>
<td>Scrub radius (mm)</td>
</tr>
<tr>
<td>Toe In &amp; Toe Out</td>
</tr>
</tbody>
</table>
Graphical Representation:

After designing in the LSA we hardpoints of the suspension system. We will use these hardpoints as the coordinates for designing the wishbones. So, for designing the Front Wishbones the coordinates are:

![Graph between Castor Vs Travel](Fig3: Graph between Castor Vs Travel)

![Graph between Toe Angle Vs Travel](Fig4: Graph between Toe Angle Vs Travel)

And for designing the Rear Wishbones the coordinates are:

![Graph between Spring Travel Vs Wheel Travel](Fig6: Graph between Spring Travel Vs Wheel Travel)

![Front Suspension Coordinates](Fig7: Front Suspension Coordinates)

![Rear Suspension Coordinates](Fig8: Rear Suspension Coordinates)
2.2 Design Of Wishbones:
Design of the suspension was carried out in Computer Aided Designing (CAD) using CATIA designing software V5R21 and SOLIDWORKS for designing purpose.
Design of wishbones is the major step to construct a suspension system. Initially, for designing we have coordinates from LSA.

2.2.1 Front Wishbones:
Double wishbone suspension system of unequal length and parallel was implemented for Front suspension.
We finalize the shape of wishbone to be A/V as it can distribute stresses over the members effectively.
Upper wishbone is shorter than lower wishbone. The advantage of having different lengths is that when the vehicle takes a turn a negative camber is induced which increases the stability. Often this arrangement is titled as SLA (Short Long Arm). As we are having damper to lower wishbone in front side so the lower wishbone will be of A shape and the front upper wishbone will of V shape. As we have caster angle 0.13 deg which makes our front suspension unequal and parallel. We will mount the spring in the lower wishbone which will be tilted towards the rear side.

2.2.2 Rear Suspension system:
It consists of equal A-arms and parallel arm design. Independent equal A-arms are widely accepted as camber changes can be easily eliminated. One end is attached to the chassis and other end is attached to the knuckle. A-arm provides large amount of travel and mostly equal the front suspension system. At rear side the camber angle and caster and also the toe angle will be zero. For making toe angle zero we are connecting a zero toe rod.
As we are having damper to upper wishbone in rear side so the upper wishbone will be of A shape and the rear lower wishbone will of V shape. As we have caster and camber angle 0 deg which makes our front suspension equal and parallel. We will mount the spring in the upper wishbone which will be tilted towards the front side.
So in this way we had designed both the wishbones. After designing of the wishbones we had done the material selection by looking into various parameters such as ultimate strength, yield strength etc. The material selection was also based upon the material strength to bear the loads acting in the dynamic condition. So the material considered according to the market availability was AISI-4130 as it was lighter in weight along with optimum cost.

Material selected - AISI 4130
- Outer diameter: 25.4mm
- Inner diameter: 19.8mm

**Physical Properties Of Aisi 4130**
- Ultimate strength: 560 MPa
- Carbon content: 0.28
- Yield strength: 460 MPa
- Elongation at break (in 50mm): 21.50%
- Modulus of elasticity: 210 GPa
- Poisson’s ratio: 0.3
- Bulk modulus: 140 GPa
- Density: 7.85 g/cm³

**2.3 Upright Design:**
Upright design is by CATIA and SOLIDWORKS software by using the proper tire dimensions. It is designed in such a way that it could hold the upper and lower pivot points of the arms and the output axle long with the hub and brake callipers without any difficulties. After the designing it is validated using the CATIA FEA package. After this it is tested by assembling all the remaining parts of the suspension system.

**III. ANALYSIS**
After designing is over in CATIA it is imported to ANSYS simulation software (Computer Aided Engineering). Analysis of suspension is done by using ANSYS software. Several types of thermal analysis, structural analysis can be made possible using ANSYS software. Here we are conducting structural analysis to define the boundary conditions and to determine the stresses and deflection developed by applying various loads.

For analyzing the whole system some basic calculations are used to calculate the values of various loads acting on it. A certain amount of force will be given in order to see the various deformations which are going to be held during simulation. So to check this we are using the FEA software ANSYS to view these deformations.

**3.1 Analysis of wishbone:**
For analysis of the wishbones a 3G newton amount of force is given to check the strength of the design of the wishbones. By this we calculated the maximum possible deformation and maximum stress developed in the arms in the impact load conditions.
3.2 Upright Analysis:
The front and rear upright are analysed by FEA analysis software ANSYS. The upright will give support to the bearings of the hub which ultimately allows the wheels to rotate. The FEA analysis is done by applying 2000N which gives some amount of red zones on the upright.

So to harden the upright we fabricated it by using aluminium alloy to give strength of that it can sustain the forces acting on it. The front upright is of material Aluminium alloy 7560 and rear upright is fabricated by using Aluminium alloy 6061-T6. Both the uprights are having different material because of their different design.

IV. RESULTS
After Manufacturing the ATV various tests are. Those tests includes both static and dynamic tests. The following results are received from static conditions:

1. Centre of Gravity Height: 18 inch
2. Ground Clearance: 13 inch
3. Roll Centre Height
   1. Front: 230mm
   2. Rear: 260 mm

Dynamic results are received by testing the vehicle in various terrains like mud, hills etc. We can further modify the suspension system of the vehicle by using trailing and semi-trailing arm at rear side in the spring will be mounted on knuckle and firewall. Trailing arm and Semi- Trailing arms will be mounted on the knuckle and the base of the chassis.

V. CONCLUSION
The paper describes about designing and analysing suspension of an All Terrain Vehicle (ATV) and their integration in the whole vehicle. The ATV has been designed and analysed based on the facts of vehicle dynamics. The primary objective of this paper was to identify the design parameters of a vehicle with a proper study of vehicle dynamics. This paper also helps us to study and analyse the procedure of vehicle suspension designing and to identify the performance affecting parameters. It also helps to understand and overcome the theoretical difficulties of vehicle design.

REFERENCES


Fig15: Stress Analysis of A-arms

Fig16: Front Knuckle
Fig 17: Rear Knuckle


Design And Material Selection Of Baja Vehicle”.

