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Design, Analysis and Fabrication of Rear Suspension System for an All Terrain Vehicle

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Abstract- All Terrain Vehicle (ATV) is defined by ANSI as a vehicle that travels on low pressure tires, which is used to handle any kind of terrain it faces. The paper focuses on design of rear suspension system for an ATV. The paper covers simulation, modeling and analysis of suspension geometry. Suspension is designed such that it provides better handling and better comfort for an ATV.

Index Terms- All terrain Vehicle, New improvised Rear Suspension, Objectives, Trailing Arm with Camber Links, Design, Analysis and Fabrication

1. INTRODUCTION:

A vehicle suspension system is a linkage to allow the wheel to move relative to the body and some elastic element to support loads while allowing that motion.
Most practical vehicles have some form of suspension, particularly when there are four or more wheels.

NEED OF SUSPENSION

The role of suspension system is to support the vehicle weight, to separate the vehicle body from road disturbances, and to maintain the contact between the tire and the road surface also to improve stability and ride comfort of the vehicle.

2. OBJECTIVES OF SUSPENSION DESIGN

- To provide greater travel, this allows better absorption of the shocks during the changes in ground conditions.
- To reduce unsprung mass so as to have lesser inertia loads, thus the response time of the suspension to changes in the track surface is minimized. This allows the tire to maintain constant contact with the surface as much as possible.
- To provide better handling while cornering by providing camber gain.
- To minimize plunging of CV-joints in suspension

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The basic criterion to achieve better handling was to have camber gain in roll. In other words, as the car corners, the goal is to gain negative camber at the outer wheels and to gain positive camber at the inner wheels of the vehicle. By providing sufficient camber gain the wheels remain vertical to the ground even when the body rolls, which provides better grip while cornering.
Also the roll centre of the rear suspension was kept higher than the roll centre in front to decrease oversteering of the vehicle.
The roll centre has a significant impact on a suspension's steering response; moreover, there is a direct correlation between roll centre location and oversteer, understeer, or neutral steer suspension behaviour depicted in Figure 1. [1]

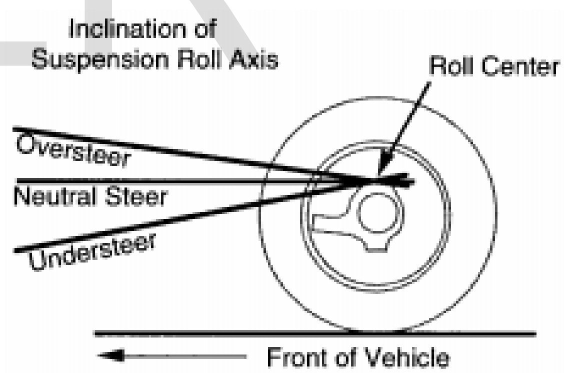

FIG 1.EFFECT OF ROLE AXIS

To start with the suspension designs firstly the vehicle parameters such as wheel track, wheel base were defined according to the rules specified by SAE BAJA which states that "Maximum dimensions of vehicle should be 64 inches width".

Considering this overall width and the size of the tire and wheel combination, the suspension must be designed such that maximum width at the tire edge surfaces is not more than 64 inches at ride height.

Table 1: Various vehicle dimensions decided.

Vehicle dimensions at ride height	Rear
Width	59 inches
Wheelbase	60 inches
Ground clearance	11 inches

The track width was kept smaller to aid in maneuverability. The wheel base was kept minimum to decrease the turning radius. To maximize obstacle avoidance, a ground clearance of 11 inches from the ground to the lowermost member on the chassis was chosen.

Recessional wheel travel is also provided which accounts for the longitudinal forces that arise during the vehicle approaches a bump.

TABLE 2: SUSPENSION SYSTEM PARAMETERS

Parameter	Value
Suspension travel in Jounce	6 inches
Suspension travel in droop	3 inches
Roll centre height	13.5 inches
Camber	10
Toe in	00
Camber gain per deg roll	0.70
Recessional wheel travel	0.5 inches
Stiffness (k) (N/mm)	Variable
Damper travel	6.2 inches

3. SUSPENSION TYPE AND GEOMETRY

The rear suspension was selected as trailing arms with camber links, also called as three link trailing arm suspension it consists of normal trailing arm and also contains two links in lateral direction which is used to carry lateral load and also controls camber through suspension travel. The configuration of this type of suspension is as shown in figure

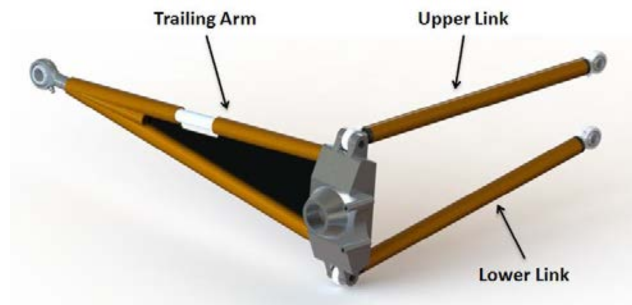

FIG 2. TRAILING ARM WITH CAMBER LINKS

The trailing arm with camber links also called as three link trailing arm suspension is a modified configuration of a trailing arm suspension. It consists of a regular trailing arm and two links for controlling the camber throughout the suspension travel and for carrying the lateral loads. [3]

Advantages of Trailing Arm with Camber Links

This type of suspension carries the following advantages over the other type of suspensions

- Better lateral load handling capacity.
- Better control over camber throughout the travel
- Better Anti-Squat properties.
- Lesser bending stress on suspension components.
- Plunging of the shafts can be minimised easily.

Disadvantages

- Increased complexity
- Increased cost

3.1 Design of Suspension Geometry

The suspension geometry was obtained by using instantaneous centre method so as to have minimum plunging of shafts. The lengths of the half shafts and the camber links were obtained from the geometry. The lengths of the camber links were to be kept maximum so as to reduce the tyre scrub. The Geometry obtained by using Instantaneous Centre Method is as shown in fig 3. [3]

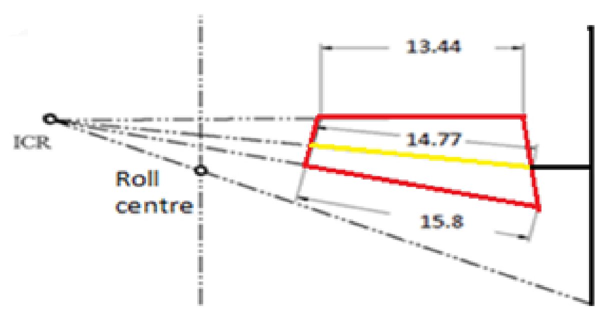

FIG 3: SUSPENSION GEOMETRY (DETERMINATION OF LINK LENGTHS)

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The mounting of the suspension was made beside the cockpit area which considerably reduced the weight of the engine compartment members. The shock absorber was mounted on the firewall itself thus the complete load from the suspension was transferred to the firewall.

Camber links were provided to achieve sufficient camber gain in roll. The camber gain also helped in reducing the plunging of the drive shafts thus preventing the shafts from popping out of the gearbox.

3.2 Simulation of Suspension Geometry

The suspension was also simulated in lotus suspension analysis software for obtaining the hard points and checking the articulation of the suspension. Number of iterations was done in lotus for optimizing the suspension performance. The software allows the user to visualise the suspension kinematics and to modify the suspension geometry.

The software also provides series of graphs such as Camber Vs Roll angle, Camber Vs Bump, Toe Vs Bump etc. The software also contains options for animation of the geometry which makes it easier to design the geometry. The figure 4, 5, 6 shows the suspension geometry in lotus suspension analysis software.

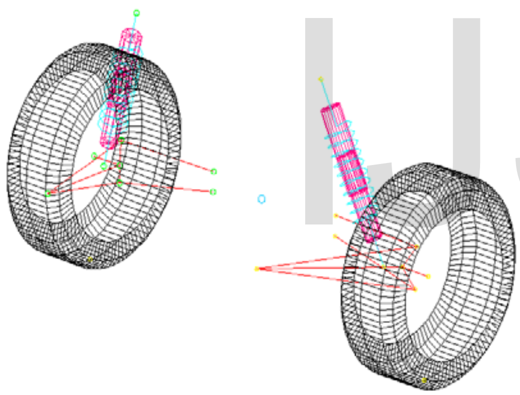

FIG 4 .STATIC CONDITION OF SUSPENSION

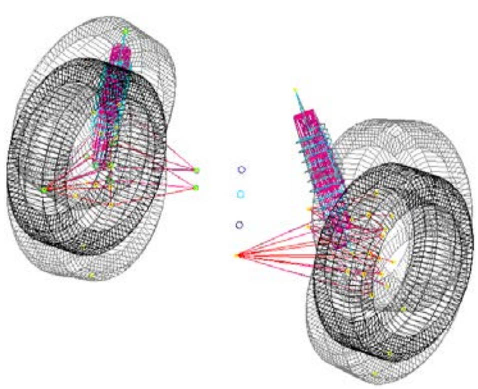

FIG 5. BUMP AND DROOP SIMULATION

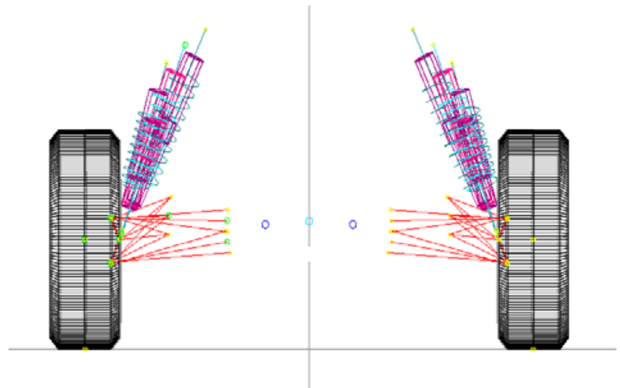

FIG 6. ROLL SIMULATION

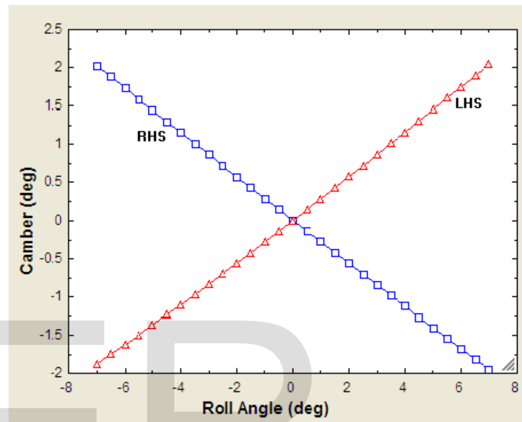

FIG 7. CAMBER GAIN IN ROLL

4. DESIGN AND MODELLING OF THE SUSPENSION COMPONENTS

The main factors for the design of the rear suspension are weight, cost and functionality. The suspension was designed to maximize travel without affecting other performance parameters. It was required to have negative camber gain in bump and positive camber gain in droop. The allotted weight for this system is 20kg.

The components to be designed are as follows

- Trailing arm
- Wheel hub
- Camber links
- Shock absorber (Selection)

Following steps were carried out for designing suspension:-

- Selection of type of suspension
- Selecting of nominal hard points of suspension
- Simulation of suspension geometry by imparting the hard points
- Modification of suspension geometry
- Confirming the suspension geometry

- Design and modelling of suspension components
- Analysis of suspension components

The various suspension components were modelled using Pro-E software as shown below.

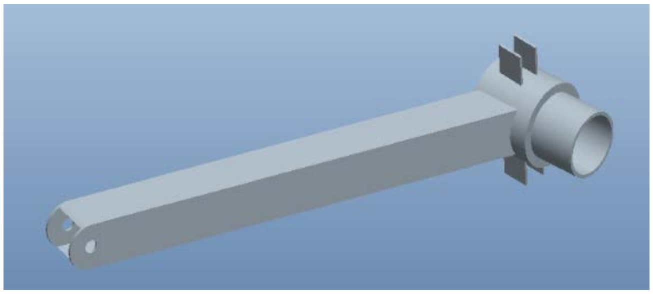

FIG 9. TRAILING ARM

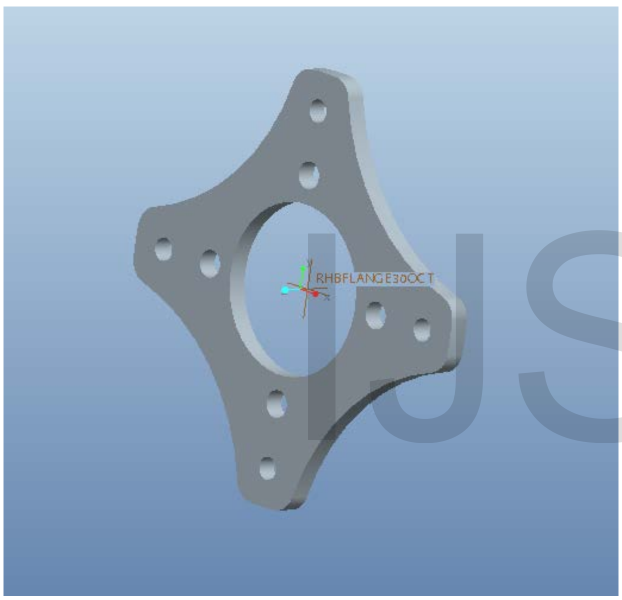

FIG 9. REAR HUB

4.1 Selection of shock absorber

Fox air suspension was selected which provides easy adjustment of stiffness and progressive damping.

The Fox air suspension also helped reducing the unsprung mass with its light weight body made of 6061 aluminium alloy and weighs around 1 kg only.

The stiffness of the shock absorber can be easily changed by changing the air pressure in the cylinder. Pressure upto 150 psi can be used.

FIG 10 . FOX FLOAT

Figure below shows the graphs between restoring force and the travel of the shocks.

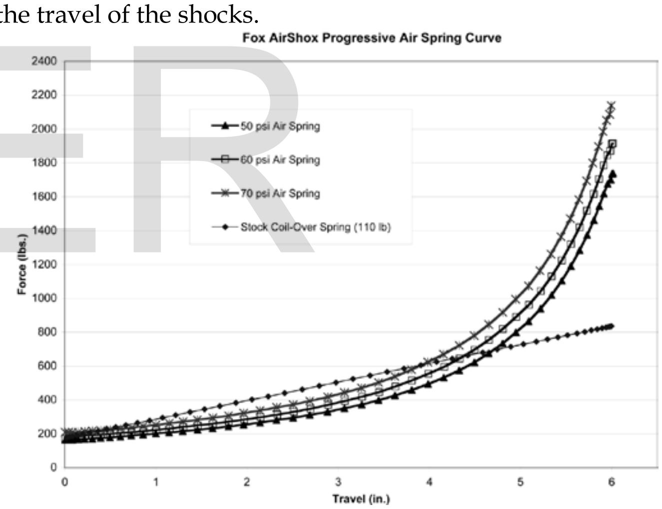

FIG 11. FORCE V/S TRAVEL

5. ANALYSIS OF THE SUSPENSION COMPONENTS

For the analysis of the suspension components, the forces acting on them were calculated.

The forces acting on them are

1. Longitudinal forces: - These forces arise due to braking and drive line forces acting on the components. The drive line forces are mostly taken by the trailing arm and the braking forces are carried by the wheel hub and the bearing carrier.

2. Lateral forces: - When a vehicle is taking turn a force equal to the centrifugal force is acted upon the contact patch of the wheel, thus a moment is

induced in the suspension components and this load is carried by the camber links as well as the bearing carrier.[5]

3. Vertical forces: - These forces arise due to the bumps in the ground. Usually 3g loads are acting on the components in case of bumps.

For analyzing the components ANSYS software was used in which the components were analysed for combined loading of the forces. Then according to the results the changes were made in the components so as to meet the objectives.

Following loads were applied for analysing the rear suspension components.

TABLE 3: REAR SUSPENSION LOADING

Rear Loading	
Direction	Force/ Moments
Longitudinal	200 Nm
Lateral	292.28 Nm
Vertical	3840 N

The figure 12 shows the ANSYS results for maximum stress induced in the trailing arm for combined loading. The maximum stress induced is 161.51 MPa which is less than the yield strength of the component i.e. 415MPa.

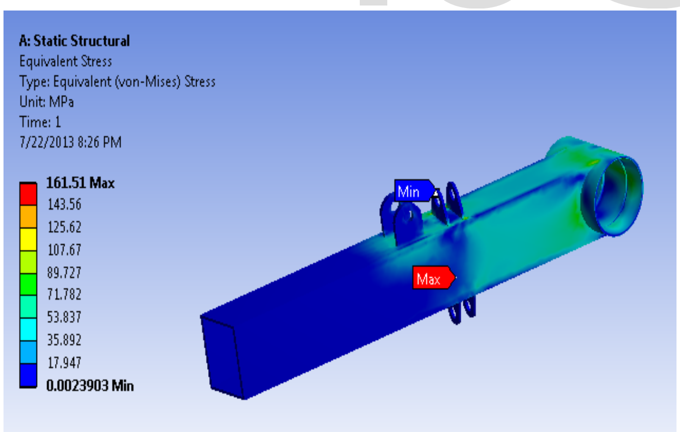

FIG 12. TRAILING ARM

The figure 13 shows the ANSYS results for maximum stress induced in the wheel hub for combined loading. The maximum stress induced is 151.3 MPa which is less than the yield strength of the component i.e. 265MPa.

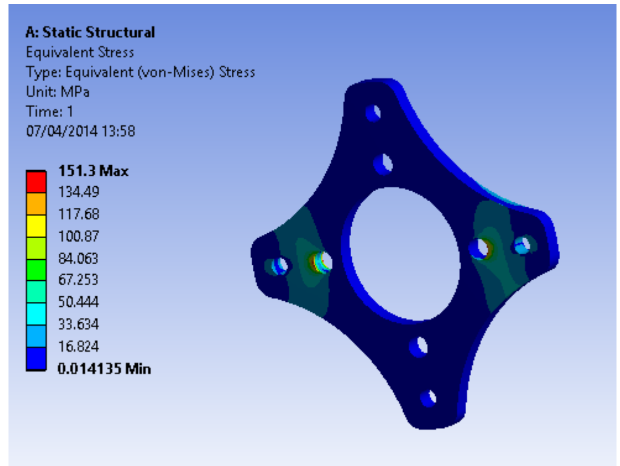

FIG 13. REAR HUB

6. FABRICATION AND ASSEMBLY

After design and analysis of the system the components were fabricated in the college workshop.
The bearing used is standard bearing of Maruti Suzuki Alto which was press fitted in the bearing carrier. The final assembly is as shown in figure 14.

FIG 14. ASSEMBLY OF REAR SUSPENSION

7. CONCLUSION

After initial testing of the Setup and its implementation on the vehicle the overall adjustability of the rear suspension meets the design goals of possessing better handling while cornering with the help of sufficient camber gain. With some adjustments to the Fox Air shocks we were able to induce under steer for the vehicle. The other design objectives of maximum travel with minimum plunging of the drive-shafts was also achieved which resulted into better driver comfort. Thus the objective of designing a light weight and rugged suspension system for an all terrain vehicle is achieved.

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