# SELECTION AND MODIFICATION OF INDEPENDENT SUSPENSION MECHANISM FOR A TERRAIN VEHICLE WITH FOUR WHEELS DRIVE

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## ABSTRACT

*In this paper a terrain vehicle with four wheels drive and four wheels steer intended to use for recreational purpose is presented. The main purpose is to design the suspension mechanism that fulfills requirements about stability, safety and maneuverability. Nowadays, as well as in the past, the development of the suspension systems of the vehicle has shown greater interest by designers and manufacturers of the vehicles. Research is focused to do a comprehensive study of different available independent suspension system (MacPherson, double wishbone, multi-link) and hence forth develop a methodology to design the suspension system for a terrain vehicle. Few chosen suspension systems are analyzed into the very details in order to find out the optimal design of it. During development process of the suspension system should be considered design constraints and requirements provided in the check list. Afterwards the simulation results for kinematics analyses of suspension mechanism are performed in Working Model 2D and MATLAB environments. Achieved results are discussed in detail in order to find the best solution that will fulfill pretentious requirement from developed suspension system. All these investigations and reviews related to the suspension system will be exploited in order to obtain the optimal suspension geometry to equip a terrain vehicle, with such system.*

**Keywords:***terrain vehicle, design, suspension mechanism, suspension geometry*

## 1. INTRODUCTION

The primary function of the suspension system of the vehicle should fulfill pretentious requirements about stability, safety and maneuverability. The suspension system of the vehicle performs multiple tasks such as maintaining the contact between tires and road surface, providing the vehicle stability, protecting the vehicle chassis of the shocks excited from the unevenness terrain, etc. [1]. The suspension system works together with the tires, wheels, frame, suspension linkages, wheel hubs, breaks systems as well as steering system to provide driving comfort, stability, etc. This system is the mechanism that physically separates the vehicle body from the wheels of the vehicle. The performance of the suspension system has been greatly increased due to the continued advancements in automobiles in the recently years. The suspension system will consider ideal if the vehicle body isolate from uneven road and inertial disturbances associated during situation of cornering, braking and acceleration. The design of the vehicle suspension system may be different for front and rear axis (independent or dependent suspension). The main aim in this research is to conceive and design the suspension system for a terrain vehicle with four wheels drive and four wheels steer intended to use for recreational purpose. The terrain vehicle it is designed to operate mostly in roughness terrain as well as in paved roads. The design of the terrain vehicle is modeled in Pro/ENGINEER environment and is shown in Figure 1.

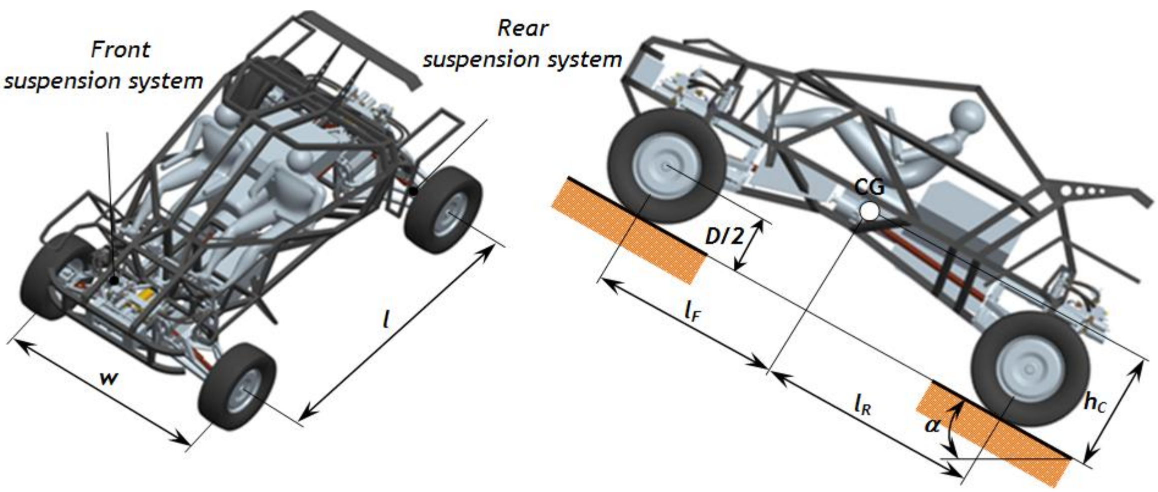


**Fig- 1**: Design of terrain vehicle modeled in Pro/ENGINEER environments

In order to meet the requirements counted in the project as better as much, in Table 1 are given check list with main characteristics, which should be respect during design.

**Table 1** - Check list with characteristics which influence in the design of the suspension system

| SN | Characteristics of terrain vehicle | Value | Unit | Remark |
|---|---|---|---|---|
| 1 | Engine Power, $P_E$ | $-4 \times 10^3$ | kW | Limit |
| 2 | Powertrain System | Mechanical | | Request |
| 3 | Driving Speed; v | 0.180 | Km/hr | Limit |
| 4 | Maximal passing road slope; a | -50 | deg | Wish |
| 5 | Geometric dimensions:<br>Wheel Base: l<br>Track width: w<br>Distance: $l_F$<br>Distance: $l_g$ | <br>2.80<br>2.10<br>1.40<br>1.40 | m | Limit |
| 6 | Total mass of the vehicle; $m_{tot}$ | 1150 | kg | Limit |
| 7 | Dimensions of front and rear wheel;<br>Diameter: D<br>Width: B | <br>0.80<br>0.25 | m | Request |
| 8 | Camber angle; γ | -0 | deg | Limit |
| 9 | Suspension system | Independent suspension | | |
| 10 | Vertical motion of wheels;<br>Rebound: $z_{min}$<br>Rest position: $Z_{rest}$<br>Bound: $Z_{max}$ | <br>-0.250<br>0<br>+0.250 | | Request |

For better understanding of the suspension design in following are discussed classification and Types of the vehicle suspension systems.

## 2. LITERATURE REVIEW

### 2.1 Types of Suspension System:

Generally, the suspension system is classified into two main types

- Dependent Suspension System
- Independent Suspension System.

### 2.1.1 Dependent Suspension System

This type of suspension system acts as a rigid beam such that any movement of one wheel is transmitted to the other wheel. Also, the force is transmitted from one wheel to the other. It is mainly used in rear of many cars and in the frontof heavy trucks. Different types of dependent suspension system are,

- Leaf Spring Suspension
- Pan hard rod
- Watt's Linkage

### 2.1.2 Independent Suspension System

This type of suspension allows any wheel to move vertical without affecting the other wheel. These suspensions are mainly used in passenger cars and light trucks as they provide more space for engine and they also have better resistance to steering vibrations. Different types of independent suspension system are

- Swing Axle Suspension
- Macpherson Strut Suspension
- Double Wishbone Suspension
- Trailing Arm Suspension
- Semi-trailing Arm Suspension
- Transverse Leaf Spring Suspension

Out of all the above mentioned independent suspension systems, Double Wishbone Suspension System is the most common type of suspension system used in the passenger cars and most of the All-Terrain Vehicles.

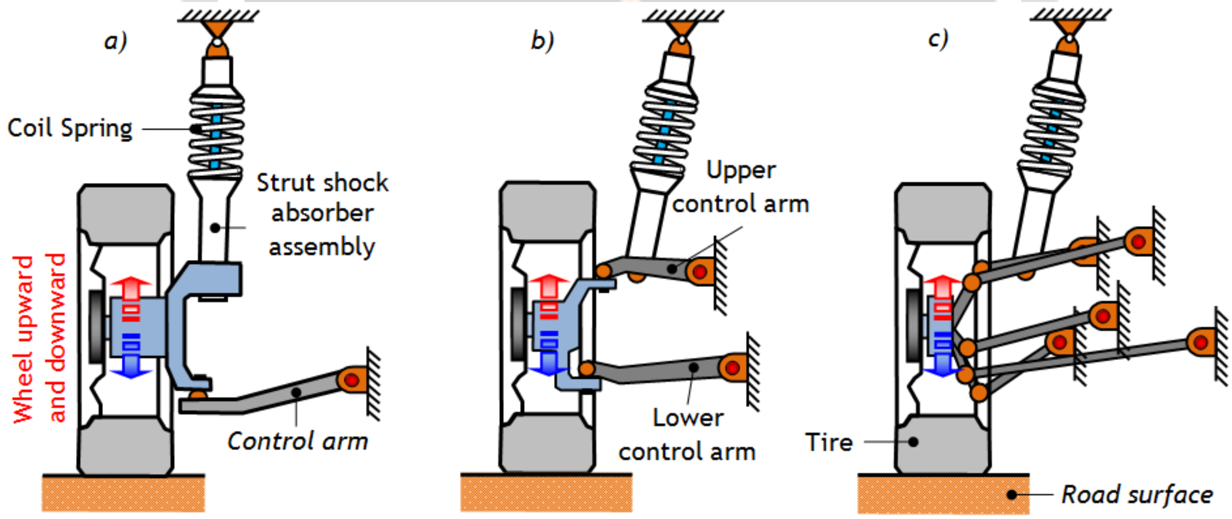


**Fig- 2**: The independent suspension system;

a) MacPherson strut b) double wishbone and c) multi–link suspension system

**2.2 Double Wishbone Suspension System**

Double Wishbone Suspension System consists of two lateral control arms (upper arm and lower arm) usually of unequal length along with a coil over spring and shock absorber. It is popular as front suspension mostly used in rear wheel drive vehicles. Design of the geometry of double wishbone suspension system along with design of spring plays a very important role in maintaining the stability of the vehicle.
This type of suspension system provides increasing negative camber gain all the way to full jounce travel unlikeMacpherson Strut. They also enable easy adjustment of wheel parameter such as camber. Double wishbone suspension system has got superior dynamic characteristics as well as load-handling capabilities.The double wishbonesuspension system in the USA often is called “A-arms” and “Double Wishbones” in UK. The double wishbone suspensions system are applied to luxury sedans and sports cars because their design of elastic – kinematic parts allow to provide an optimum compromise between handling and comfort. The double wishbone used two lateral control arms to hold the wheel from tilting with suspension action. The upper and lower control arms usually are with unequal length where the acronym SLA (short-long arm) gets its name. During design of this type of suspension, it is required careful refinement of suspension geometry in order to get good performance.
There are a few advantages of the double wishbone suspension system, e.g. the primary benefit is increase negative camber as a result of the vertical motion of the upper and lower arms. This justify to stability performance for the vehicle as the tires on the outside maintain better contact with the road surface during cornering. Disadvantages of the double wishbone compared with MacPherson strut suspension system, becomes in the complexity of the design, production cost, increased number of parts such as joints and bearing which have negative consequences on the tire wear due consumption of bushing rubber.

## 3. DESIGN OF THE WISHBONES SUSPENSION SYSTEM

Initially, the material is selected usingPugh’s Concept of Optimization. Based on the properties of the selected material, the allowable stress is calculated using sheer stress theory of failure. The roll-centre is determined in order to find the tie-rod length. The designed wishbones are modeled using software and then analyzed using Ansys analysis software to find the maximum stress and maximum deflection in the wishbone.

### 3.1 Material Selection of Wishbone

Material consideration for the wishbone becomes the most primary need for design and fabrication. The strength of the material should be well enough to withstand all the loads acting on it in dynamic conditions. The material selection also depends on number of factors such as carbon content, material properties, availability and the most important parameter is the cost.By using Pugh’s concept of optimization, we have chosen AISI 1040 for the wishbones. The main criteria were to have better material strength and lower weight along with optimum cost of the material.

#### 3.1.1 Pugh’s Concept

This is a method for concept selection using a scoring matrix called the Pugh Matrix. It is implemented by establishing an evaluation team, and setting up a matrix of evaluation criteria versus alternative embodiments. This is the scoring matrix which is a form of prioritization matrix. Usually, the options are scored relative to criteria using a symbolic approach (one symbol for better than, another for neutral, and another for worse than baseline). These get converted into scores and combined in the matrix to yield scores for each option.

#### 3.1.2 Comparison of Materials

The properties of the above mentioned materials which were considered for wishbones are as follows,

**Table 1**: Properties of Materials

| **Properties** | **AISI 1018** | **AISI 1040** | **AISI 4130** |
|---|---|---|---|
| Carbon Content (%) | 0.18 | 0.40 | 0.30 |
| Tensile Strength (MPa) | 440 | 620 | 560 |
| Yield Strength (MPa) | 370 | 415 | 460 |
| Hardness(BHN) | 126 | 201 | 217 |
| Cost (Rs./metre) | 325 | 425 | 725 |

**3.2 Stress Calculation**

For ductile materials, allowable stress is obtained by the following relationship

$$\sigma = \frac{Syt}{fs} \quad .................. (1)$$

Assume factor of safety, fs = 1.2 (as AISI 1040 is a ductile material)

$$\sigma = \frac{415}{1.2}$$

$$\sigma = 345.83 \text{ MPa}$$

This is the value of allowable stress value in the wishbones. The designed wishbone is safe when the induced stress is lesser than the allowable stress value. The allowable stress is determined using Ansys analysis software.

**3.3 Determination of Roll Centre**

Roll Centre in the vehicle is the point about which the vehicle rolls while cornering. There are two types of roll centresthe geometric roll centre and force based roll centre. The roll centre is the notional point at which the cornering forces in the suspension are reacted to the vehicle body. The location of the geometric roll centre is solely dictated by the suspension geometry, and can be found using principles of the instant centre of rotation.
Determination of roll centre plays a very important role in deciding the wishbone lengths, tie rod length and the geometry of wishbones.

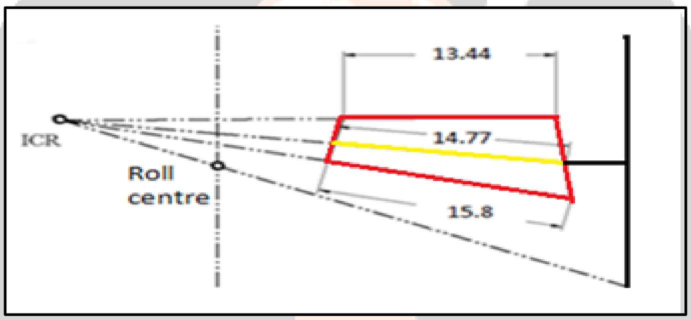


**Fig-3:**Determination of Roll Centre

Roll centre and ICR is determined because it is expected that all the three elements- upper wishbone, lower wishbone and tie rod should follow the same arc of rotation during suspension travel. This also means that all the three elements should be displaced about the same centre point called the ICR. Initially, wishbone lengths are determined based on track width and chassis mounting. These two factors- track width and chassis mounting pointsare limiting factors for wishbone lengths. Later, the position of the tire and the end points of upper arm and lower arm are located.
The vehicle centre line is drawn. The end points of wishbones are joined together to visualize the actual position of the wishbones in steady condition. When the lines of upper and lower wishbones are extended, they intersect at a certain point known as Instantaneous Centre (ICR). A line is extended from ICR to a point at which tire is in contact with the ground. The point at which this line intersects the vehicle centre line is called the Roll Centre.Now, extend a line from ICR point to the steering arm. This gives exact tie rod length in order to avoid pulling and pushing of the wheels when in suspension.

## 4. CONCLUSIONS

This paper present design of the suspension mechanism intended to use in a terrain vehicle with four wheels steer and four wheels drives. The main aims are concentrated to design an independent suspension system to provide better contact of tire with road surface and less lateral displacement of the tire. Following are derived some important conclusions, such as:

- Designed suspension system provides 45% less displacement of the wheel in lateral motion. When wheel is pushed upward situation is better and provides 72.6% less displacement compared with same double wishbone suspension system,

- Designed suspension system provides relatively small values of camber angel nearly to zero which influence to have better contact of the tire with road surface. This improve, is a result that suspension mechanism allow wheel respectively tyre to acts perpendicular in road surface.
- The large vertical motion of the wheels (– 250 ... 250 mm) will be caused a lot of problems in steering mechanism. The large vertical motion should be not influence on the contra torque on the steering wheel, but have ability to rotate the wheel around the kingpin axes for minor angle thus causing the vehicle to decrease stability. To avoid this problem completely new design of steering mechanism should be done.

## 5. FUTURE SCOPE

- The stipulated objectives namely providing greater suspension travel,reducing the unsprung mass of the vehicle, maximizing the performance of the suspension system of the vehicle andbetter handling of vehicle while cornering; have been achieved.
- The suspension system can be further modified for decreasing the weight and cost. Transverse leaf spring can be usedto decrease the weight of the suspension assembly. Pneumatic suspensions can be incorporated in the future for betterperformance.

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## BIOGRAPHIES

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