A Comparative study of the Suspension for an Off-Road Vehicle

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Abstract - *Humans use different vehicles to travel in different terrains for comfort and ease of travel. An off-terrain vehicle is generally used for rugged terrain and needs a completely different dynamics in suspension comparison to an on-road vehicle. The aim of this project is to identify and determine the parameters of vehicle dynamics with a proper study of suspension and to initiate a comparative study for an off-road vehicle using different models.*

***Key Words*: Suspension, Vehicle Dynamics, Off-road Vehicle, Control arms, Camber**

1.INTRODUCTION

Suspension

The role of a suspension system within a vehicle is to ensure that contact between the tires and driving surface is continuously maintained. Also to provide a smooth and comfortable ride for the riding personnel. It must also absorb the vertical accelerations created by the wheels when the vehicle is in motion. A wide variety of components are utilized to achieve the desired travel as well as compression for absorption. These components include vibration during the travel, springs for compression, control arms for flexibility, and lastly ball joints.

Control Arms

Control arms serve as the connecting link between a vehicle's chassis and suspension system. The role of the control arm is to hold all the components within a vehicle together while it undergoes a vertical movement. Vehicles typically have two categories for suspension; dependent suspension systems and independent suspension systems.

1.1 Types of Suspension

Dependent suspension systems are essentially a beam connecting two wheels that transmit any movement or loads to both of the wheels. Although dependent suspensions add quite a bit of rigid strength to a vehicle as well as simplicity and lower cost there are many more disadvantages to their use. Today this type of suspension is usually only used in heavy industrial applications where that type of strength is typically needed. Some of the main disadvantages to using a dependent system is there excessive unsprung weight, which in turn need a heavy spring to be able to hold it.

Another major issue is their lack of adjustability since everything is rigidly attached meaning that once everything is set nothing can be adjusted or moved. This type of suspension will not be considered in the scope of this project largely due to its lack of adjustability.

Independent suspension systems provide more effective functionality in traction and stability for off-roading applications. Independent suspension systems provide flex (the ability for one wheel to move vertically while still allowing the other wheels to stay in contact with the surface).

There are many different versions and variations of independent suspensions, which include swing axle suspensions, transverse leaf spring suspensions, trailing and semi-trailing suspensions, Macpherson strut suspensions, and double wishbone suspensions. Control arms are used for far more than just component support as they can provide adjustments in not only the positions of shock assemblies but also provide adjustments and flexibility in wheel alignment as well.

1.2 Elements of Suspension

Camber:

Camber is defined as the vertical alignment of wheels and is measured as an angle from the vertical axis of a suspension. A vehicle can have positive or negative camber depending on the setup of the vehicle. Positive camber is taken to be when the top of a wheel is pointed outward away from a vehicle and the bottom of the wheel is pointed inward towards the vehicle, Whereas negative camber is taken to be when the top of a wheel is pointed inward towards the vehicle and the bottom of the wheel is outward away from the vehicle.

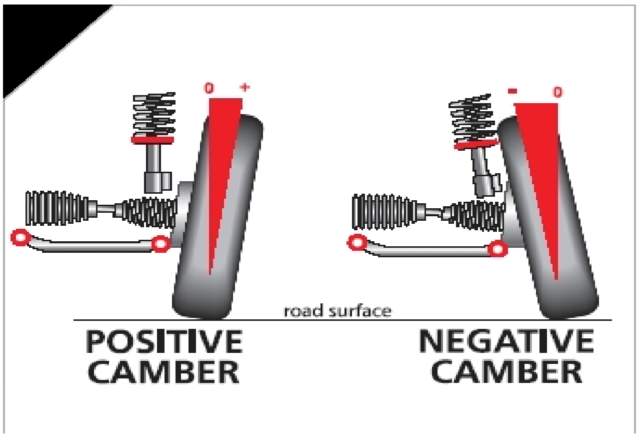

Fig-1: Camber

A camber angle produces a camber thrust, which pulls the bottom of a wheel into the direction the top portion of the wheel is facing. Positive camber is typically not used because it increases the chances of a rollover-taking place and is unstable in high speed and off-roading applications. Negative camber, however, can prove to be useful in off-roading applications. A wheel with negative camber can assist in the turning of a vehicle as it can maintain as much contact with the surface as possible, thus giving it more grip as well as stability.

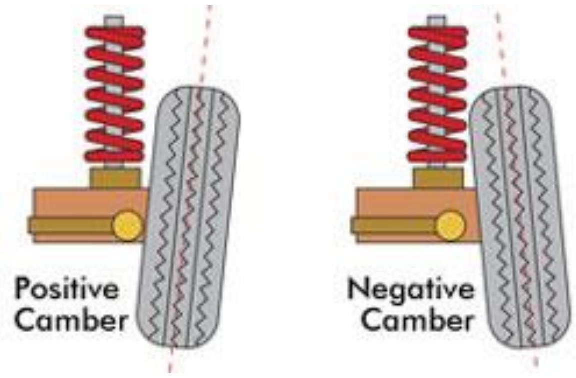

Fig-2: Positive and Negative Camber

2. SUSPENSION AND CONTROL ANALYSIS

For an off-terrain vehicle, the swing axle suspension is not considered because it cannot support large deflections and does not have very good handling capabilities. The transverse leaf spring suspension, although used in high performance vehicles, is not viable due to our selection of coil over springs and also due to its cost. This suspension utilizes leaf springs made of composite materials, which are typically very expensive. The suspensions types that are suitable include the MacPherson, double wishbone, semi trailing and trailing arm suspensions.

Typically, the semi trailing and trailing arm suspensions are used in the rear of a vehicle while the MacPherson suspension and the double wishbone designs can be used in both the front and rear. The MacPherson suspension is also called a single control arm suspension and consists of a strut or shock assembly, wheel hub and one control arm. Both the strut and control arm connect directly to the chassis of the vehicle. The control arm then connects to the bottom of the wheel hub, whereas the strut connects to the top of it.

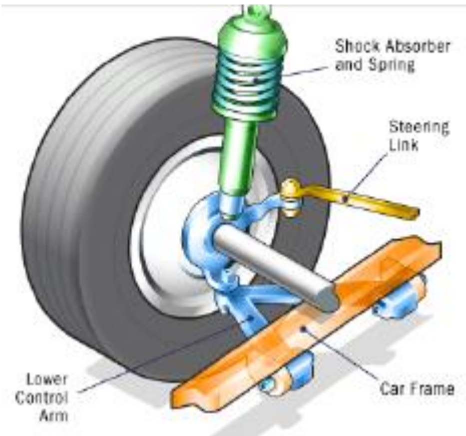

Fig-3: MacPherson Suspension

The advantages of a MacPherson suspension are its simplicity, low number of mechanical components that reduce failure points, low cost, lightweight, and a large amount of space allowing for ease of component integration. Its disadvantages, however, include an increased ride height due to its vertical space and lack of camber adjustments which means turning is more difficult.

A semi-trailing and trailing arm suspensions are typically used in the back of a vehicle. Trailing and semi trailing arm suspensions are almost identical as they are both pivoting arms attached to the chassis of the vehicle. These arms are placed in front of the wheel creating the trailing effect. The difference between the two arises in the position of the pivot points. Trailing arms have their pivots positioned perpendicular to the vehicle's centreline while semi-trailing arms have their pivots positioned at an angle to the centreline.

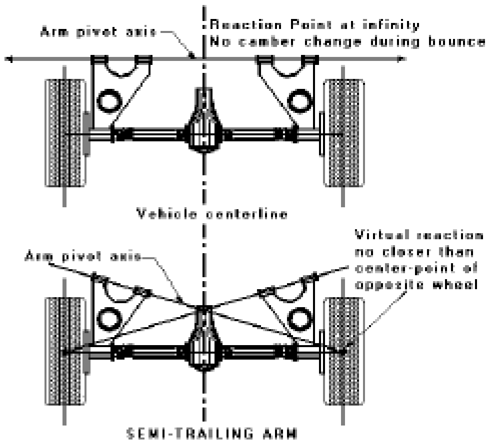

Fig-4: Trailing Arm vs Semi-Trailing Arm

In general, both arms share the same advantages, which include a rigid design, simplicity, and very few mechanical components. However, a semi-trailing arm has slightly better steering properties than a trailing arm due to the angle found on the semi trailing arms.

This allows for camber effects, which the trailing arms are not capable of. In the case of the semi arm, its angles provide a trailing section and a transverse section, which provide under-steer and over-steer respectively.

3.SHOCK ASSEMBLY ANALYSIS

A shock assembly is a combination of several components that work together to successfully absorb or dampen forces, as well as support the weight of the vehicle and keep the tires on the driving surface. One of the most recognized components of a suspension system is known as springs, which expand and compress to dampen out the vertical forces presented by a wheel. There are a wide variety of different springs that can be used on vehicles, such as coil-over springs, leaf springs, torsion bars, and air springs. In terms of designing an off-terrain vehicle only air and coil-over springs are typically considered. This is largely due to them being relatively lightweight, low in cost, and high in functionality.

Air Shocks and Coil-overs:

Coil-overs feature two main components; coil springs and shock absorbers. The coil springs provide a means of absorption for the vertical accelerations that a wheel undergoes when in contact with a rough surface or bump. This absorption is essentially the transformation of the wheel's kinetic energy into potential energy by compression. Once the spring is compressed it will decompress and transfer the potential energy back down to the wheel. Thus, causing the wheel to rebound back down to the surface. The shock absorber controls and dampens the spring's oscillation. This prevents the springs from oscillating countless times until all energy is released and allows the wheels to stay on the surface.

Air shocks, function very differently. An air shock consists of a sealed air cylinder with a rod inside. The air cylinder is filled with both nitrogen and oil. The oil controls the compression and rebound of the shock and nitrogen control the height. Essentially air shocks perform the functions of both springs and shocks in one unique system.

Air shocks are typically highly and easily adjustable, lightweight, and low cost. Adjustability is perhaps the biggest advantage as they are simply made by adjusting oil and nitrogen levels to acquire the desired ride. Air shocks, however, have some disadvantages. Air shocks are less durable, require more maintenance, and are unable to rebound as quickly as coil-over. They offer better overall performance, durability, rebound rate, rebuild ability, and the ability to utilize the full length of the spring as opposed to air shocks. As far as disadvantages with coil-overs they are not as adjustable, and typically are more expensive with a wide range of prices depending on brand and model.

4.COMPARITIVE ANALYSIS

The first model under consideration for analysis is Model-1. The is generally preferred because of its exceptional adjustability. The Model-2 series shocks had a better gripping power. The next model looked into was Model-3 and they offered 2.0" individual air shocks. Model-4 also happened to make 2.0" coil-over suspensions but had better adjustability.

Loads of the springs included with the Model-5 shock assembly were 19,973 N/m for the front spring and32,343 N/m for the rear springs. This model of shock assembly offers mechanical performance similar to the previous models.

The resultant load on the vehicle is found by,

Front & Rear Loads:

(Total Weight – 600 kg) * (Weight Percentage - 0.60) = **160 kg - Rear load**

(Total Weight – 600 kg) * (Weight Percentage - 0.40) = **110 kg - Front load**

Individual Spring Load:

(Rear Load – 360 kg) / (Number of Springs - 2) = **80 kg Per Spring**

(Front Load – 240 kg) / (Number of Springs - 2) = **55 kg Per Spring**

The following table exhibits the comparison of the performances of the different models.

Models	Type	Radius	Maximum Force
Model-1	Air	0.75	198 kg
Model-2	Coil	1.00	160 kg
Model-3	Air	1.00	360 kg
Model-4	Coil	1.00	200 kg
Model-5	Coil	1.06	120 kg

Table -1: Comparative analysis of shocks

The more the force and the diameter of the model, the more is the ability of the model to accept the shocks.

5. CONCLUSIONS

Different models of suspension were analyzed and the factors affecting it were thereby derived.

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