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Double Wishbone Suspension System; A Research

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Abstract: ***Advancements in science and technology, effective designs and newly advanced ways of manufacturing for the need to fulfill the customer expectations and to provide them better goods has let to these developments. With the invent and help of numerous mechatronic systems there is technological advancements in various automobile sectors and thus gave better performance output A suspension system has responsibility of safety of both the vehicle and occupants by providing stability and comfort ride during its maneuvers. Without the help of any suspension system, it would have made extremely hard for a driver to control a vehicle since all the shocks and vibrations would have been directly transmitted to steering without any damping. The main aim of this study to discuss about the designing and analysis of double wishbone suspension system for automobile.***

Keywords: ***Dependent Suspension, Independent Suspension, Double Wishbones, spring and Damper System***

I. INTRODUCTION

Suspension is the system that connects vehicle body (chassis) to its wheels and allows relative motion between the two and hence isolating the vehicle from road shocks. Suspension system consists of springs, dampers (shock absorbers), linkages, tiers and air which are filled in those tires which absorbs shocks and provides better road holding/handling and ride quality to occupants during driving, cornering and braking. To provide cushioning effect to occupants and safe vehicle control it is important for the suspension to keep the wheels in contact the with road surface as much as possible, because all the reaction forces from ground which are acting on the vehicle do so through the contact patches made between ground and tires. Suspension system doesn't let all the weights on wheel directly and hence also reduces wear on tire. There are different types of suspension systems are available shown in Figure 1.[1] The spring rate (or suspension rate) is a deciding component to know the vehicle's ride height above the ground such that it doesn't damage the vehicle while driving over potholes and speed breakers, hence it also give idea about how much a suspension system can be compressed (suspension stroke). Force exerted by vehicle on suspension is proportional to change in length of spring where spring is either compressed or stretched based on situation. Spring rate for a spring is defined as weight required for one inch deflection in spring, stiffer springs require more weight and softer springs require less weight for unit inch of deflection. There are variable spring rates which can have both stiffer and softer spring rates in one spring called as progressive rate spring;

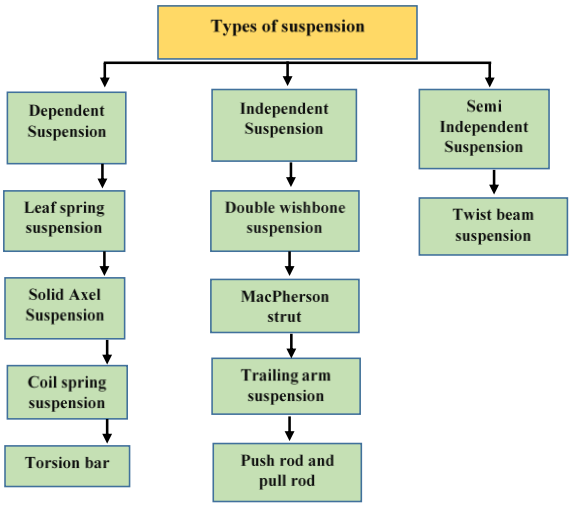

Figure 1. Different types of suspension systems

This kind of spring has multiple spring rates. Spring rates also commonly known as spring constant is an important criteria to measure how much resistance is offered by a spring to force (weight) by undergoing deflection [1].

As the vehicle move over the terrains the vehicle will rise and fall it may leads to damage the parts .to overcome this they have divided into two separate areas, these are

1. Suspension dynamics
2. Suspension kinematics

Suspension dynamics depends on the road condition and amount of force which are applied when vehicle passes and take results of it. So that we can chose the type of suspension can used and damper to optimize those values. Suspension kinematics as the vehicle rises and falls where the position changes and the amount of travelled,

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where should the suspension must be placed at what point must be attached can be seen By considering this we can conduct on different material and properties of it can be changed and assess how good this configuration will provide good control to vehicle, which will provide better contribution than other material and what is wanted from vehicle. Suspension kinematics

Camber kinematics: when vehicle moves at high speed and corners they might tilt, at that time chamber thrust acting on the wheel experiences the cambering and results in force and lean. The negative cambering helps to improve grip while cornering and the tiers are better placed at angle to the road and the important part of positive cambering is they create more stability of the vehicle and doesn't need much effort while steering. When the vehicle rises and falls the camber change so that outer wheel go towards negative camber as the vehicle corners and have best use of camber thrust , this control of camber is called camber compensation [2], [3]. Before starting designing and analyze the suspension system, we must be familiar to some concepts that play major role in design procedure. These terms act as both controlling parameters as well as design variables in design.

1. Track width
2. Wheel base
3. Camber Angle
4. Toe angle
5. Kingpin Inclination angle
5. Sprung weight
6. Weight distribution

A. Caster angle:

Caster angle is an angle made by the kingpin (steering axis) with the vertical axis passing through the wheel center when seen through side of wheel. Castor angle plays a very influential parameter with respect to dynamic behavior of the vehicle. It is a directional stability oriented property which helps the wheel to lead in same direction as the vehicle moves (trailing effect), hence trail reduces driver effort. Incorrect caster angle results in hard steering, lack of directional stability and vehicle pulls to one side when brakes are applied. Positive carter angle is responsible for steering centric restoring force i.e. after taking turn by rotating steering wheel and if we remove hands from steering wheel it re-center itself.

B. Camber:

Camber also plays important parameter with respect to dynamic behavior of the vehicle. Camber is defined as the angle between center line of wheel (wheel plane) and the vertical axis of wheel when viewed from front of vehicle. Camber angle is one of the parameters which decides suspension's positioning and wheel alignment. If wheel alignment is not correct then there will be different rate of wear within a tire. Camber angle can have both negative as well as positive orientation. Camber is considered negative if the top of the wheel leans inwards and it is widely used in racing cars since it benefits while cornering and more surface is in contact with road. Camber is considered positive if the top of the wheel leans outwards this type of camber is used in normal vehicles so that when vehicle is loaded it automatically comes to vertical position which is very much favorable for uniform wearing of tire. Proper camber also provides required centripetal force while cornering.

C. Kingpin Inclination and Scrub Radius:

Kingpin are mounted in such a way that they slant inward this angle at which kingpin axis (steering axis) is inclined to the vertical axis passing through the wheel center is called kingpin axis inclination. While taking a turn vehicle body is lifted slightly due to kingpin inclination and after completing turn if driver leaves the steering wheel then vehicle weight causes the wheel to recover straight ahead. Therefore kingpin angle affects the performance of the vehicle when the wheels are steered, Hence both caster and kingpin inclination contributes to directional stability of vehicle. When the kingpin axis is extended such that it intersects the ground at a particular point, then distance of that point from the center of wheel contact patch is called scrub radius. If scrub radius is more, then wear of the tire is also more but by increasing kingpin inclination scrub radius can reduced and negative scrub can also be achieved .Some amount of negative scrub radius is suggested so that the wheel roll easily when steered but excess kingpin inclination also increases lift of the car while steering.

D. Toe:

Toe is the symmetrical angle that both the wheels of front or rear axle makes with the longitudinal axis passing through center of gravity of the vehicle, when viewed from top. As a function of static geometry, kinematic and compliant effects, toe is final parameter used to describe a vehicle's alignment. Since it is important and deciding parameter in wheel alignment, tire wear is heavily dependent on the toe distances. There are two types of toe, toe in and toe out. In rear wheel drive cars, increased positive toe angle (toe in) at front tires provides greater straight-line stability at the cost of slowing down in steering response by some amount. Whereas toe out is preferred in front wheel drives vehicles. Many dynamic factors can change the toe angle, and toe angle can be adjusted by adjusting tie rods of steering [3].

In a suspension system roll center can be defined as a point in the Trans axial plane of the axles, about which vehicle tends to roll due to lateral forces while cornering.

E. Geometry of Roll center

Roll center can be defined in two different ways, one based on geometric roll center (kinematic roll center) and another based on force roll center. While designing of suspension system we consider geometric based definition, because it plays a very important role in deciding the wishbone arm lengths and the geometry of wishbones. Geometric roll center also helps in determining length of tie rods, it is expected that both upper and lower wishbones and tie rods in a suspension system follow same arc of rotation while cornering whose center is known as instantaneous center. Center of gravity of mass is calculated, if there is a difference between roll center and center of mass then a moment arm is created in between them.

Vehicle while cornering experiences angular velocity and if moment arm length is more, then tendency of vehicle rolls is more since moment thrust due to moment arm will be more. Therefore size of moment arm, anti-roll bars and stiffness of spring decides how much vehicle will roll. Hence high roll center and low center of mass is required to lower moment arm length, high roll center can be achieved by lowering the inner ball strut [4].

F. Design of wishbone suspension

Wishbones is the important parts of the suspension system. The wishbones is designed in such a way that the roll center is located close to the center of gravity of vehicle and the distance of roll center is near to ground. Caster, camber and kingpin inclination should be considered while designing knuckle and wishbone. Wishbone lengths are obtained by wheel track width and chassis mounting points. These are A- shaped links made from steel. These have to withstand great bending force, partial impact loading due to bumps and potholes. The dimensions of control arm are defined by keeping in mind of required function and outcomes. Therefore design procedure includes combination of both loading criteria and suspension geometry. The material selection is done based on the strength, cost and are highly preferred in industry. All these parameters help for analyze and designing of suspension system [5].

II. LITERATURE SURVEY

Now a days, various methods of modeling and designing double wishbone suspension one among them is spatial RSSR-SS linkage approach for modeling, in this type of modeling first suspensions are identified as 3-D mechanism with one degree of freedom then secondly matrices are formed for displacement, velocity and acceleration are formed to each suspension link` to describe the mechanism motion with loop closure constraint equations. Then this displacement matrix method is used for kinematic synthesis and analysis of suspension mechanisms is focused on designing the suspension system by optimizing certain suspension performance indices, such as camber angle, caster, toe, and king-pin inclination and classifying them into two objective functions related to controllability and stability performances. The multi-objective optimization using the distance function method. However, in these works, the kinematic constraint equations are used just for formulating the constrained optimization problems. The authors utilized a Design of Experiments module in the software Adams\View to obtain the optimal values for the key design parameters of the suspension system by setting up the desired ranges for those design parameters [6].

However, active suspension is a one of the advance type of suspension that actively controls the vertical movement of tires relative to the chassis of vehicle with help of preprogrammed computer control system, feedback system of sensors and actuators. Riding quality can be improved by reducing rolling effect by the help of independent force applied by actuators on suspension without causing any change to dynamic properties. Working of this system can be explained as, When there is any change in road condition or any disturbances on the road that can be sensed by various compatible sensors which act as input or feedback system to the electronic control unit (ECU) [7].

Here we have discussed the controlling device checks for any error in the input signal, and if the error is found it immediately tunes actuator to act accordingly on the situation by exerting extra force on the suspension system. Thus, in most of the driving conditions like normal driving, cornering, and braking, an active suspension can identify and fulfill the need such that it almost eliminates rolling and pitching of the vehicle body. We can notice and conclude that the drawback of conventional or passive suspension has been overcome by active suspension since it enhances both the comfort of passengers and maneuverability properties of the vehicle without compromising on any of them. There are two ways active suspension can be divided into namely semi-active suspension and fully active suspension. Semi-active or adaptive suspension is only known to change the viscous damping coefficient of the shock absorber, hence changes and increase absorber firmness only such that it matches the changes in road and dynamic conditions. Whereas in fully automated along with changing and increasing the absorber firmness it also uses actuators for raising and lowering the chassis independently at each wheel [8]. Moreover, we have discussed the modeling of double wishbone suspension using Simulink application of MATLAB software, Simulink uses the mathematical model derived for quarter car suspension as input for analysis and gives results. In quarter car suspension we will be dealing with the quarter mass of the vehicle, one wheel, one shock absorber, and one spring. Therefore the analysis is carried out based on the mathematical model obtained, results are compared and body acceleration is obtained for combinations of various assumed values of suspension parameters like the stiffness of spring and damping coefficient of the shock absorber. We have also compared the results between active and passive suspension [9]. However, there are different steps involved in metamodeling are, to design the suspension experiment it on stimulation and select the material which is suitable. They developed more model and different types to get more accurate. They have studied 4 modeling technique which are polynomial regression, Kriging model, MARS, and RBF based on multiple performance criteria. By doing these experiments we came to know about the efficiency, transparency and conceptual simplicity over other meta-models [10].

While stimulating the choice of sampling points is more important, a number of sampling points lead to more accuracy, majority of all vehicle parameter will be assumed because of insufficient data of real world and lack of information. Here we have discussed the important factors for designing and analysis purpose like, loads, design, material properties, boundary condition, manufacturing service, aging factor, all of these are assumed so they couldn't get the expected performance goal. In order to enhance the performance and safety they have used the software, The Reliable Based Design Optimization (RBDO) and the Robust Design Optimization (RDO) represent two major paradigms for the design.

RBDO are used for analytical techniques to find the failure points and other criteria reliability suspension performance. RDO it will improve the quality of the product by minimizing the other effects. Both the RBDO and RDO are used for analysis vehicle dynamics [2], [11].Moreover, here we are discussing the basics of suspension and working of the damper. When a vehicle passes on the irregular surface the suspension will absorb the shock and gives a comfortable ride.

There are different types of dampers used for suspension. The most frequently used dampers for the road are hydraulic, double tube and high pressured gas dampers. The hydraulic damper is widely used in Macpherson strut suspension. While cornering at high speed sometime the car may roll over to overcome this we have made a good design, parameters of suspension, characteristics of tiers, good steering. For suspension, we have to know more about double wishbone and have to analysis them[4].

However, the suspension plays a major role in formula cars. Especially for race cars, double wishbone suspension will have either pull rod or pushrod and should be lighter components. Generally, formula cars use pushrod in the front and pull rod in the rear, it is more popularly used in all formula cars. Designing the suspension is more complicated, it must have the proper procedure. Here we have discussed the designed the upper A-arm and lower A-arm pushrod with a spring damper. It is carried out by assuming the geometry of all the points since it is difficult to find [3].

Moreover, the double wishbone is a type of independent suspension system, it has got its name as wishbone since its arm shape resembles that of a wishbone of a bird. This type of suspension is also termed as short and long arms suspension (SLA). Double wishbone suspension has two arms known as the upper arm (shorter) and lower arm (longer), each arm has two mounting points one connected to chassis of the vehicle and another one to knuckle by a spherical joint. Double wishbone arms are also called as double A-arms. Between arms, there is a coil spring and shock absorber present which controls the vertical movement. A double wishbone has superior dynamic characteristics to react instantaneously to changes and good load handling capabilities, therefore it is commonly used in sports cars and racing cars. A single wishbone can be used in a variety of other suspensions like MacPherson strut in which unsprung masses can be reduced. The double wishbone suspension provides the engineer more design choices and it is fairly easy to find out the effect by moving each joint, so the kinematics of the suspension can be tuned easily and wheel motion can be optimized. It also increases negative camber as a result increases stability since more area of tires is touching the road. Hence wheel alignments remain consistent as well as steering[12], [13].

III. RESULTS AND DISCUSSION

Thereafter, we have discussed the kinematics and dynamic performance of the suspension system. The kinematic performance is vehicle handling and the dynamic performance are ride comfort. Thereafter, we have compared the different suspension systems, after the comparison, the double wishbone suspension is better performance but has complicated structure The geometry of double wishbone provide excellent parameters to the vehicle, the linkage can either acts as tension or compression And can be made light in weight. To design the wishbone we should know the dimensions of chassis and their mounting points, to get the perfect design and it minimizes the polar moment and drag while racing. It is desirable for racing not for road car because of more space required, as the linkage is lightweight it is preferred for race cars like Formula cars. They are called an upper A-arm and lower A-arm when hit the uneven surface, the A-arm will move vertically and provide stability. Un-sprung weight: less amount will be acting on [14], [15].

IV. CONCLUSIONS

Designing the suspension is more complicated, it must have the proper procedure. In this paper, we have discussed the important points for designing and analysis of double wishbone suspension system.

- Still, need to explore the new modeling and Optimization methods.
- That provides easy design and easy manufacture
- Still, need to improve the stability and control by roll center
- Still, need to explore the different camber angle and toe angle while traveling the vehicle.
- Still, need to improve the mounting points
- Optimal Spring constant and damper ratio is required
- Weight of the vehicle and person which can be withstand

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