

Modification of Double Wishbone Suspension System Using Electromagnetic Shock Absorber

Abhijith K, Arun R Menon, Ajith K Jayan, Anusree V Anand

Student, Dept. of Mechanical Engineering, Royal College of Engineering and Technology, Kerala, India

Student, Dept. of Mechanical Engineering, Royal College of Engineering and Technology, Kerala, India

Student, Dept. of Mechanical Engineering, Royal College of Engineering and Technology, Kerala, India

Student, Dept. of Mechanical Engineering, Royal College of Engineering and Technology, Kerala, India

ABSTRACT: This paper discusses with the modification of the double wishbone suspension by replacing the conventional fluid damping in the shock absorber with an electromagnetic damper. For a vehicle its suspension system keeps an important role in making it stable and keeping the vehicle in control. A suspension system is also responsible for smoothing out the ride. Different types of automobile suspension systems have been introduced to maximize the comfort of passengers and to promote the driving experience. But the road conditions like potholes and irregularities have made it to fail the comfort of passengers inside. The suspension system is made up of different components that all work together to absorb the energy created by bumps and holes in the road. If the degree of dampness offered by the dampers used in the suspension system could be controlled according to the road condition, the riding quality could be improved. The Electromagnetic Suspension system uses the opposing magnetic field developed by eddy current induced on a conductor placed in a magnetic field in accordance with lenz's law. This opposing magnetic field is used to provide the damping action and the degree of dampness can be controlled by varying the magnetic field. The Electromagnetic suspension consists of a set of electromagnets along with a coil spring. The electromagnet arrangement provides sufficient damping action and the damping can be varied in accordance with road conditions. The suspension system is designed using Inventor 2018 software and the electronic circuit is simulated using Proteus 8 software.

KEYWORDS: Double wishbone suspension, Inventor 2018, Electromagnetic shock absorber

I. INTRODUCTION

The suspension system of an automobile keeps a vital role in ensuring the comfort of the passengers inside and also it makes the vehicle stable in different road conditions. Suspension is the system of tires, tire air, springs, shock absorbers and linkages that connects a vehicle to its wheels and allows relative motion between the two. Suspension systems must support both road holding/handling and ride quality, which are at odds with each other. The components of the suspension system perform six basic functions: Maintain correct vehicle ride height, Reduce the effect of shock forces, Maintain correct wheel alignment, Support vehicle weight, Keep the tires in contact with the road and Control the vehicle's direction of travel. But in case of potholes and speed bumps the suspension system fails to keep its duty. When a vehicle passes over a disturbance on road, its tire and the suspension attached to the tire also get disturbed which leads to a discomfort to the cabin. If the disturbance on road is deep (pothole) and the vehicle passes over it at a high speed the suspension may fail to keep the stability of vehicle. This leads to accidents. The Electromagnetic Suspension system is introduced to avoid these problems due to different road conditions.

In this paper, it is proposed to replace the conventional damper with an electromagnetic arrangement [3]. This uses the repulsive behavior of two electromagnets to provide necessary damping and its control along with a coil spring. The coil spring provides a minimum damping for bearing the weight of vehicle and passengers and for further damping the electromagnetic system is employed. By varying the magnetic field, the damping action can be controlled. These systems allow for greater suspension articulation when driving under low-yaw circumstances (driving relatively straight) to absorb road irregularities and have a much more rigid response when the car is driven through turns, which improves vehicle dynamics. To facilitate the ideal suspension with regard to comfort, handling, and safety, various commercial technologies are used to improve or replace the conventional passive suspension system.

II. DOUBLE WISHBONE SUSPENSION SYSTEM

Double wishbone suspension system is an independent suspension system containing two wishbone shaped control arms to locate the wheels. Steering knuckle connects the two control arms mutually and also with wheel. The other end of control arms is mounted to the chassis. A shock absorber is mounted between lower wishbone and body to restrict the motion of the suspension. Double wishbone suspension is very convenient to be redesigned such that the motion of the wheels can be controlled by changing the control parameters such as camber angle, caster angle, toe, roll center height etc.

A. Design

The basic design of the double wishbone suspension is not changed here. Only the shock absorber is being modified. (Design calculations are referred from [1] & [3]). The suspension system is designed with the help of Inventor 2018 software and checked the conformity using the software itself. In addition to the existing design an electric circuit is needed for sensing and controlling the suspension. The designing and testing of electric circuit is done using Proteus 8 software.

Fig.1 shows the proposed double wishbone suspension containing lower and upper A arms connected with steering knuckle via ball joints and wheel assembly. In the design the normal design of the shock absorber is changed. The fluid damping unit in the conventional shock absorber is replaced with a piston cylinder arrangement containing two repelling electromagnets. The diameter of the cylinder is increased to accommodate the electromagnetic coils. Also the piston is made to be hollow cylinder for reducing cross sectional area and convenience. Fig.2 shows the sectional view of the modified shock absorber.



Fig.1 3D Design Of Double Wishbone Suspension Using Inventor 2018

One of the electromagnetic coil is fixed on the bottom of the cylinder and other one is placed on the end of the piston as shown in fig.3. The piston is placed inside a coil spring with necessary stiffness. The piston is locked inside the cylinder using a locking lid (part 3 in fig 2). It also helps in compressing the spring. The electromagnetic coils are connected with an additional electrical circuit for sensing and actuating the electromagnetic damping. When the circuit is powered, the coils produces magnetic field which are repelling in nature. This repelling magnetic field creates a counter force when there is a relative motion between piston and cylinder.



S Spring Index : 8.890

The length of cylinder can be taken according to the bound and rebound of tires. While designing this model, the maximum vertical travel of the wheel is taken as 100 mm and weight distributed over the right side front suspension is assumed as 200 kg (1962 N). The factor of safety is set to be 1.2. But in actual case, these values cannot be used since these values are very less for any kind of vehicle. But these values are intentionally taken for keeping a better proportionality in modifying the design.

The electromagnetic coils are wound with a 18.5 SWG Insulated Copper wire having a core diameter of 25mm and 2000 turns (approximately). Since the current flowing through the circuit is DC, thick wires are used for winding to have low resistance, low voltage and high current. The ends of the coils are taken out and connected to a circuit having a linear potentiometer sensor. The entire circuit is powered by the car battery itself. The coils are connected in series. The linear potentiometer sensor senses the vertical motion of the lower wishbone and controls the magnetic field between the coils.

B. Suspension Properties

- angle between the vertical axis of the wheels used for steering and the vertical axis the vehicle when viewed from the front or rear.
- 4. Ground clearance :- It is the amount of space between the base of an automobile tire and the lowest point. 135mm as per design.
- 5. King pin inclination In the designed suspension King pin inclination is made zero. King pin is set at an angle to the vertical plane. When viewed from the front or rear of the vehicle. This angle is known as King pin inclination.
- 6 Front and rear track :- As per design front and rear track at 1580mm. The axle track in automobiles and other wheeled vehicles which have two or more wheels on an axle, is the distance between the centre line of two road wheels on the same axle. In a vehicle with two axles, this is expressed as front and rear track.

Other properties are not mentioned. Properties like ground clearance and roll center can be changed by changing the king pin inclination

C. Electromagnetic Coil Calculations

Lorentz force is the combination of electric and magnetic force on a point charge due to electromagnetic fields.

The force developed by the solenoid is given as,

$$F = \frac{\mu_0 n^2 i^2 A}{2g}$$

Where, n = number of turns = 2000 i = current = 48 A

μ₀ = magnetic conductivity = 4π × 10⁻⁷

A = area in length per unit squared = 0.0165m²

g = length of gap between solenoid and conductor = 0.14m

$$\begin{aligned} \text{Therefore, Force } F &= \frac{(2000 \times 48)^2 \times 4\pi \times 10^{-7} \times 0.0165}{2 \times 0.14} \\ &= 4874.726\text{N} \end{aligned}$$

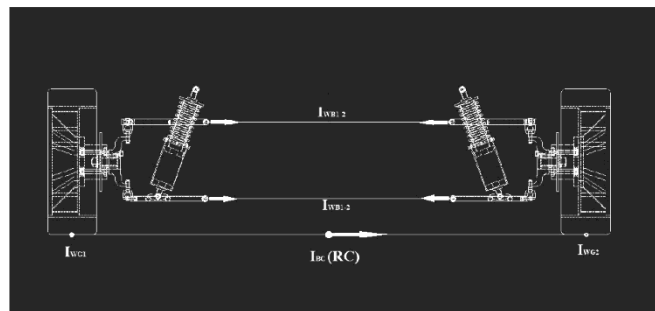


Fig.4 Suspension System Diagram

The calculated force is sufficient for taking up the vertical forces produced by the wheel movement (Assuming the weight distribution on each wheel to be 200kg or 1962N).

D. Electrical Circuit

1. Roll center :- The designed suspension have parallel control arms as shown in fig.4. Instantaneous centers IW_x and IW_z will be at infinity. So the roll center is at the ground. Roll center can be roughly defined as an imaginary point about which a body rolls, due to high lateral forces. When applied to vehicles, it's a point about which a vehicle body rolls when acted upon by lateral forces
2. Castor angle :- In the designed suspension the castor angle is made to be zero. Castor angle is the angular displacement of the steering axis from the vertical axis of a steered wheel in an automobile, measured in the longitudinal direction.
3. Camber angle :- In the designed suspension camber angle is made zero. Camber angle is the angle made by the wheels of a vehicle specifically. It is the

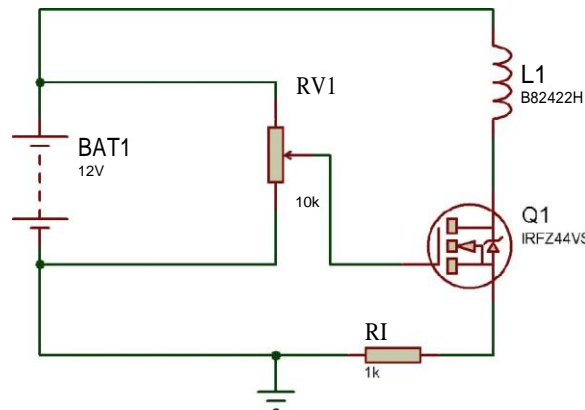


Fig.S Circuit diagram developed using Proteus 8

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The Fig.5 shows the electrical circuit which consists, S Linear potentiometer sensor

- S Battery
- H Electromagnetic coil winding
- S Mosfet
- S Resistor

A potentiometer sensor measures the distance or displacement of an object in a linear or rotary motion and converts it into an electrical signal. Here a VLP1522 series linear potentiometer is used for detecting the vertical motion of the tires. The fixed end of the sensor is mounted on the body and the movable end is connected to the lower wishbone. As the tire vertically moves the lower wishbone also moves in a reduced rate. So this deflection is measured with the linear potentiometer and corresponding electrical signals are produced. Since the battery, coils and linear potentiometer is connected in series, the deflection in linear potentiometer causes a deflection in the magnetic field created by the coils. So the repulsive magnetic field inside the cylinder is controlled according to the change in road levels which creates a controlled damping.

The MOSFET (Metal Oxide Semiconductor Field Effect Transistor) is an important element in embedded system design which is used to control the loads as per the requirement. Many of electronic projects developed using MOSFET such as light intensity control, motor control and max generator applications. The MOSFET is a high voltage controlling device provides some key features for circuit designers in terms of their overall performance. The MOSFET transistor is a semiconductor device which is widely used for switching and amplifying electronic signals in the electronic devices. The MOSFET is a three terminal device such as source, gate, and drain. The MOSFET is very far the most common transistor and can be used in both analog and digital ckt. Here the mosfet amplifies the response signal generated by the sensor to have a corresponding change in the current flow. A resistance is added for the protection of the mosfet.

E. Working

The double wishbone suspension in the design is not different from the existing ones, but the shock absorber is modified here. In this design the shock absorber doesn't contain fluid damping. The fluid damping is replaced by an electromagnetic set up. The damping unit contains two coils inside the cylinder one placed on the

bottom of the cylinder and one placed on the end of piston. The coils are connected to a circuit which is powered from the car battery. The circuit contains a active displacement sensor (Linear Potentiometer) placed on the lower wishbone, which senses the vertical movement of tire by sensing the motion of lower wishbone. The vertical movement of the tire is then sensed and the magnetic field of the coil is controlled by changing the current flow. The output rating of a car battery is usually in the range of 30-48 A (based on the Ah rating) and 12V.

So the electrical circuit is designed to be compatible with this the weight of vehicle is carried by the spring. Then additional forces are damped by the damping unit which works by the repulsion between the coils. Each coil is designed to withstand the impact forces. When the tire or lower wishbone moves upward the linear potentiometer senses the change and reduces the current flow, reducing the magnetic field. When the magnetic field is decreased, the dampness also reduces. This effects in the independent vertical motion of the tire. So the other parts remain unaffected ensures comfort of passengers inside. For example, if the vehicle approaches a hump the dampness of damper is reduced gradually as it passes over the hump corresponding to the vertical motion of tire. So the tire moves independently and it helps the vehicle to pass over a obstacle without any slowing down.

Currently the suspension designed in this project is a basic design and it doesn't specifies to any existing vehicles. But the design can be easily modified and integrated to any vehicles by altering the dimensions and electric circuits according to the requirements. The performance of the suspension can be enhanced by employing a electronic control unit which can enhance to performance of the circuit and damping unit.

III. VALIDATION AND RESULT

The designing is carried out with the help of different designing softwares such as Autodesk Inventor 2018, Proteus 8, Auto CAD etc. The 3D model of the suspension system is generated using the Inventor 2018. The designing of the double wishbone was based on the reference journal [1]. The journal contains the simulated analysis of the double wishbone suspension. So this simulation results are adopted in this project and it validates the design of the double wishbone suspension system. The degrees of freedom of the suspension system is analyzed using the Inventor 2018. It found satisfactory.

Normally the weight of the vehicle is carried on the spring it self. The electromagnetic damper unit is designed to take up the impact loads and reactions of tires. So initially

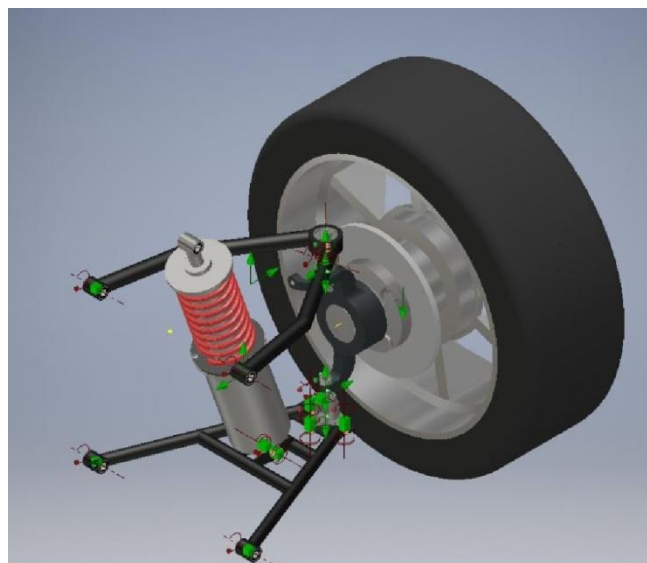


Fig.6 DOF Of Suspension System

A. Analytical Method

Analytical method is nothing but calculation of forces. For initiating analytical method the weight distribution over the suspension system and tires are assumed. Since the suspension system considered is non

driving front right side suspension, only the weight distribution on right side front tire is taken into account. The weight acting upon the tire and suspension system is assumed to be 200kg or 1962N. The wishbones plays no role in taking up the load, so the load is assumed to be concentrated on the shock absorber. The designing of spring is carried out based on this criteria. By analyzing various coil springs, a coil spring containing 9 turns, 90mm diameter, 9.1mm wire diameter and a load capacity of 2494.47N is chosen. The spring chosen provides a factor of safety around 1.2. the design was based on the concept that, the total load (weight of vehicle and passengers) will be carried by the spring and additional forces such as impact forces, reactions due to irregular road surface etc. Will be carried by the damper. So the spring chosen is found capable of carrying the loads.

The next part of analytical method is to determine the capability of the electromagnetic damper. From the calculations it is found that the coils are capable producing a force of 4874.726 N. Here, the coils are placed in such a way that when it is powered it produces a repulsive force between them. Each coil produces 4874N force and when it is set to be in repulsive it will be capable of providing sufficient damping for the shock absorber. The various losses that coils may have is also considered and the coil are still capable of providing necessary damping. The amount of dampness required and designing of the electromagnets may vary according to the vehicle which the suspension is being fixed.

On the analysis of a suspension system the suspension parameters are important. In this project the control arms are made parallel to generate a basic raw design. So the roll center is found in the ground level and caster angle, camber angle and king pin inclination has become zero. By changing the king pin inclination, the suspension parameters can be modified accordingly.

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