# Magnetic Suspension for Motorcycles

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**Abstract:** ***Suspension is a mechanical arrangement contributing to vehicle's road handling behavior. If roads were perfectly flat with no irregularities, suspensions wouldn't be necessary. It's these imperfections that apply force to the wheels .There are many types of suspensions such as double wishbone, trailing arm and air shocks. But these suspensions possess some disadvantages such as vibration, mechanical failure and stiffness variation. So in this paper we have introduced the idea of "MAGNETIC SUSPENSION" which will enhance the driving pleasure and control over road. Magnetic suspension will allow us to get variable stiffness and much higher comfort just by playing with magnetic field. It will also allow us to reduce wear and tear along with less maintenance. The magnetic suspension has two cylindrical tubular structure having electromagnets on both ends. The magnetic field will be induced using battery power which is produced by electromagnets using a feedback loop. Also when current passes through a wire, a magnetic field around that wire is generated. When the current through the wire stops, so does the previously generated magnetic field. The strength of the generated magnetic field is proportional to the rate of current through the wire. When a wire is coiled, this generated magnetic field is concentrated to the centre of the coil. The strength of this field can be increased by placing a ferromagnetic material in the centre of the coil. The arrangement will be in such a way that same poles will be facing each other resulting in repulsion of the magnets. That is either (+) positive - (+) positive or vice versa. Reducing vehicle's vibrations while travelling on irregular roads, the magnets will act as dampers and damping effect will be produced due to repulsion between them. Moreover stiffness can also be controlled by varying magnetic field according to the requirement.***

**Keywords:** Magnetic Suspension, Coil Spring, Design Parameter, Electromagnets

## 1. Introduction

Electromagnetic suspension (EMS) is the magnetic levitation of an object achieved by constantly altering the strength of a magnetic field produced by electromagnets using a feedback loop. In most cases the levitation effect is mostly due to permanent magnets as they don't have any power dissipation, with electromagnets only used to stabilize the effect.

According to Earnshaw's Theorem a paramagnetically magnetised body cannot rest in stable equilibrium when placed in any combination of gravitational and magnetostatic fields. In these kinds of fields an unstable equilibrium condition exists. Although static fields cannot give stability, EMS works by continually altering the current sent to electromagnets to change the strength of the magnetic field and allows a stable levitation to occur. In EMS a feedback loop which continuously adjusts one or more electromagnets to correct the object's motion is used to cancel the instability. Many systems use magnetic attraction pulling upwards against gravity for these kinds of systems as this gives some inherent lateral stability, but some use a combination of magnetic attraction and magnetic repulsion to push upwards. Magnetic levitation technology is important because it reduces energy consumption, largely obviating friction. It also avoids wear and has very low maintenance requirements. A model of the Magnetic Shock Absorber based on the application of magnetic property like when the same poles of two magnets come in contact with each other then they are repulsed from each other. This unit is mounted in vehicle such as other type of shock absorber. The working of this absorber is very simple. Two magnets are mounted in this way that one is mounted below and other is on upper side. Poles of these magnets are same at inner side so that they are repulsed from each other and space is made between them due to this. When the vehicle is running on the bump or the muddy road then the space between two magnets is reduced and then shocks and variations present in the vehicle absorbed by repulsion property of the magnet.

The automobile chassis is mounted on the axles not direct but through form of springs. This is done to isolate the vehicle body from the road shock which may be in the form of bounce pitch, roll or sway. These tendencies give rise to on the uncomfortable ride and also cause additional stress in the automobile frame & body. All the part which performs the function of isolating the automobile from the road shocks are collectively called a Suspension System. It includes the springing device used & various mounting for the same. Broadly speaking, suspension system consist of a spring & damper. The energy of road shock cause the spring to oscillate. The oscillations are restricted to a reasonable level by the damper, which more commonly called a Shock Absorber.

### 1.1 Objective

- To prevent the road shocks from being transmitted to the vehicle Components.
- To safeguard the occupants of vehicle from road shocks.
- To preserve the stability of the vehicles in pitching or rolling while in motion.
- To reduce the maintenance as well as initial cost.
- To increase the life of coil spring.
- To reduce the overall cost and weight of the vehicle.
- To prevents the vehicle body and frame from road shocks.
- To gives the good road holding while driving, cornering and braking.
- To gives cushioning effect.

### 1.2 Electromagnets

When a changing current passes through a wire, a magnetic field around that wire is generated. When the current through the wire stops changing, so does the previously generated magnetic field. The strength of the generated magnetic field is proportional to the rate of change in current through the wire. When a wire is coiled, this generated magnetic field is concentrated through the center of the coil. The strength of this field can be greatly increased by placing a ferromagnetic material in the center of the coil.

Although a continuous change of electric current is required to maintain a magnetic field in an electromagnet, this field is easily manipulated by passing a varying current, such as AC current, in the wire. Therefore, electromagnets are much more practical than permanent magnets for levitation purposes.

To reduce average power requirements, often the electromagnetic suspension is used only to stabilise the levitation, and the static lift against gravity is provided by a secondary permanent magnet system, often pulled towards a relatively inexpensive soft ferromagnetic material such as iron or steel.

## 2. Literature Review

A motorcycle's suspension serves a dual purpose: contributing to the vehicle's handling and braking, and providing safety and comfort by keeping the vehicle's passengers comfortably isolated from road noise, bumps and vibrations. The typical motorcycle has a pair of fork tubes for the front suspension, and a swing arm with one or two shock absorbers for the rear suspension.

A shock absorber (in reality, a shock "damper") is a mechanical or hydraulic device designed to absorb and damp shock impulses. It does this by converting the kinetic energy of the shock into another form of energy (typically heat) which is then dissipated. Most shock absorbers are a form of dashpot.

Pneumatic and hydraulic shock absorbers are used in conjunction with cushions and springs. An automobile shock absorber contains spring-loaded check valves and orifices to control the flow of oil through an internal piston. One design consideration, when designing or choosing a shock absorber, is where that energy will go. In most shock absorbers, energy is converted to heat inside the viscous fluid. In hydraulic cylinders, the hydraulic fluid heats up, while in air cylinders, the hot air is usually exhausted to the atmosphere. In other types of shock absorbers, such as electromagnetic types, the dissipated energy can be stored and used later. In general terms, shock absorbers help cushion vehicles on uneven roads.

**Figure 1**: Ohlins Suspension for Motorcycles

**Figure 2:** Cross-sectional view of the Ohlins Suspension

### 2.1 Difference between Magnetic Shock Absorber and Spring Shock Absorber

**Table 1:** Difference between two shock absorbers

| *Sr. No.* | *Magnetic Shock Absorber* | *Spring Shock Absorber* |
|---|---|---|
| 1 | It has more life | It has less life |
| 2 | Life is nearly about approximately 20 years | Life is nearly about approximately 10 years |
| 3 | The weight of magnet is more | The weight of spring is low as compared to magnets |
| 4 | If the power of magnets decreases then it is possible to recharge and it able to use again and again | Its strength at spring is decreased or loss it is necessary to replace it new one |
| 5 | It has very low maintenance | It has more maintenance |

### 2.2 Working Principle of Conventional Shock absorber

In a vehicle, shock absorbers reduce the effect of traveling over rough ground, leading to improved ride quality and vehicle handling. While shock absorbers serve the purpose of limiting excessive suspension movement, their intended sole purpose is to damp spring oscillations. Shock absorbers use valving of oil and gasses to absorb excess energy from the springs. Spring rates are chosen by the manufacturer based on the weight of the vehicle, loaded and unloaded. Some people use shocks to modify spring rates but this is not the correct use. Along with hysteresis in the tire itself, they damp the energy stored in the motion of the unsprung weight up and down. Effective wheel bounce damping may require tuning shocks to an optimal resistance.

Spring-based shock absorbers commonly use coil springs or leaf springs, though torsion bars are used in torsional shocks as well. Ideal springs alone, however, are not shock absorbers, as springs only store and do not dissipate or absorb energy. Vehicles typically employ both hydraulic shock absorbers and springs or torsion bars. In this combination, "shock absorber" refers specifically to the hydraulic piston that absorbs and dissipates vibration. Now composite suspension system are used mainly in 2 wheelers and also leaf spring are made up of composite material in 4 wheelers.

Shock absorber device was used for reducing the effect of sudden shock by the dissipation at the shock's energy on an automobile springs & shock absorber are mounted between the wheels and the frame. When the wheel hit a hole or a raised spot on a road. The spring's absorber the resultant shock by expanding & contracting. To prevent the spring from shacking the frame excessively, their motion is restrained by shock absorber, which are also known by the more descriptive term dumpers.

### 2.3 Working Principle of Magnetic Suspension System

Magnetic Suspension or magnetic ride control is a type of suspension system where the shock absorbers reacts to the road and adjusts much faster than regular absorbers. Magnetic suspension can adapt to uneven road surfaces several hundred times per second, in fact it takes only a few milliseconds to adjust any one of the shock absorbers. Magnetic suspension is described as the fastest reacting suspension in the world as sensors monitor the road surface up to 1000 times per second and an ECU can make variations within a few milliseconds resulting in the possibility of multiple damping variations being made in a second. Magnetic ride control uses a system known as magneto rheological technology for suspension damping. Each absorber is filled with a polymer liquid containing many small magnetic particles. An electrical charge is sent to the liquid in the absorber which immediately changes the position of the particles in the liquid and its viscosity. The viscosity of the polymer liquid can be changed to an almost solid state similar to plastic or rubber in composition. As the viscosity of the liquid changes, it offers a difference in the damping. Each of the four dampers are adjusted individually and independently even when it seems that all of them are doing the same thing. This ensures a comfortable ride along various road surfaces.

Magnetic suspension reduces vibrations, bouncing, noise and body roll very effectively on all road surfaces and at any speed that the vehicle could travel. The reduction of body roll may reduce the need for anti- roll bars. Another benefit is that these dampers easily offers the best of both worlds in the ride comfort/handling compromise that many other suspension systems are subjected to. Although this type of suspension offers a very comfortable ride, sport settings can be applied or tuned into the system to cater for performance vehicles.

Magnetic Shock Absorber which is mainly based on the principle of magnetic property like when the same poles of two magnets come in contact with each other then they are repulsed from each other. This unit is mounted in vehicle such as other type of shock absorber. The working of this absorber is very simple. Two magnets are mounted in this way that one is mounted below and other is on upper side. Poles of these magnets are same at inner side so that they are repulsed from each other and space is made between them due to this. When the vehicle is running on the bump or the muddy road then the space between two magnets is reduced and then shocks and variations present in the vehicle absorbed by repulsion property of the magnet. By using this type of absorber we can absorb the more number of shocks and variations are absorbed with the more accuracy. This shock absorber has no problem of leakage of oil like hydraulic shock absorber. Also this has less maintenance than other types of shock absorber. So that we can made this type of shock absorber for the efficient work of vehicle and for reducing the maintained cost of vehicle.

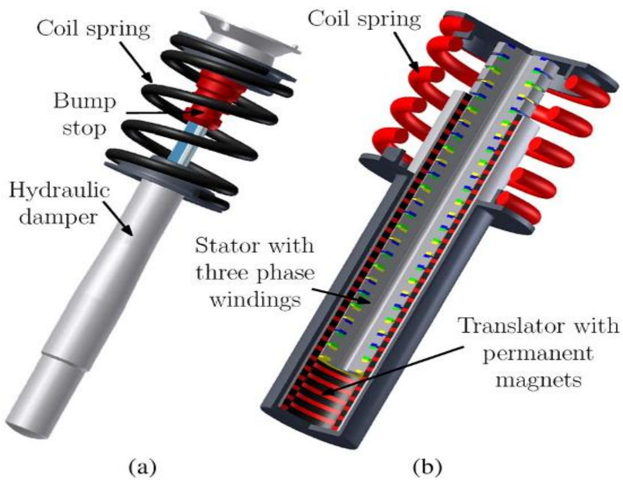


**Figure 3:** Magnetic Suspension System


**Figure 4:** Rear Suspension of a Motorcycle

## 3. Types of Magnetic Suspension Absorber

### 3.1 A Permanent Magnet Shock Absorber

A Permanent Magnetic suspension apparatus for maintaining a spaced relationship between a first movable member and a second fixed member, wherein the motion of the movable member requires dampening, cushioning, stabilizing, harmonic balancing, and/or reflexive re-centering.

The suspension apparatus includes a plurality of sets of permanent magnets located within a case, which is coupled to one of the members. The sets of permanent magnets are coupled to an elongated support member, which is couple to the second member. The support member extends within the case, with the support member and the case being adapted for relative axial movement.

The sets of permanent magnets are arranged in bidirectional repulsion configuration with additional magnet fixed within the case. the sets of permanent magnets are being moved relative to the fixed permanent magnets, such that the magnetic forces of repulsion produced by the permanent magnets are increased in response to relative movement between the support member and the case, creating dampening, cushioning, stabilizing, harmonic balancing, and/or re-centering forces.

In one embodiment, the control mechanism is coupled between the frame of a vehicle and a wheel support assembly. The permanent magnetic suspension apparatus, however, is for use with any type of equipment or machinery having a movable and non-movable, or fixed, member. this includes, but is not limited to, cars, trucks, motorcycles, scooters, all-terrain vehicles, semi-tractors, semi-trailers, and the like, as well as, but not limited to, industrial equipment and machinery, hospital and office machinery and equipment, such as being coupled between the frame of an office chair and the chair seat.

### 3.2 Regenerative Electromagnetic Shock Absorber

A regenerative electromagnetic shock absorber comprising: a linear electromagnetic generator comprised of a central magnet array assembly comprising a central magnet array comprised of a plurality of axially-aligned, stacked cylindrical magnets having like magnetic poles facing one another, a plurality of high magnetic permeability, high saturation magnetization, central cylindrical spacers positioned at each end of said stacked central magnet array and between adjacent stacked central magnets, and a magnet array support for mounting said magnets and said spacers; an inner coil array comprising a plurality of concentric cylindrical coil windings positioned adjacent to said central spacers and said magnetic poles of said central magnets, said inner coil windings surrounding an outside perimeter of said central spacers, said inner coil array mounted on a movable coil support, said movable coil support providing for reciprocating linear motion of said coil array relative to said magnet array; and an outer magnet array assembly comprising an outer magnet array comprised of a plurality of axially-aligned, stacked concentric toroidal magnets having like magnetic poles facing each other, said outer magnet array surrounding said inner coil array, said stacked outer concentric magnets being aligned and positioned essentially coplanar with said stacked central cylindrical magnets with the magnetic poles of said outer magnets aligned with and facing opposing magnetic poles of said central cylindrical magnets, and a plurality of high permeability, high saturation magnetization, outer concentric toroidal spacers positioned at each end of said stacked outer magnet array and between adjacent stacked outer magnets, said outer magnet array assembly attached to said magnet array support; wherein a predetermined location, configuration and orientation of said central magnet magnetic poles, said central spacers, said inner coil windings, said outer magnet magnetic poles and said outer spacers provide for superposition of a radial component of a magnetic flux density from a plurality of central and outer magnets to produce a maximum average radial magnetic flux density in the inner coil windings; and a voltage conditioning circuit electrically connected to said coil windings, said voltage conditioning circuit providing an output voltage and output current to an electrical load.

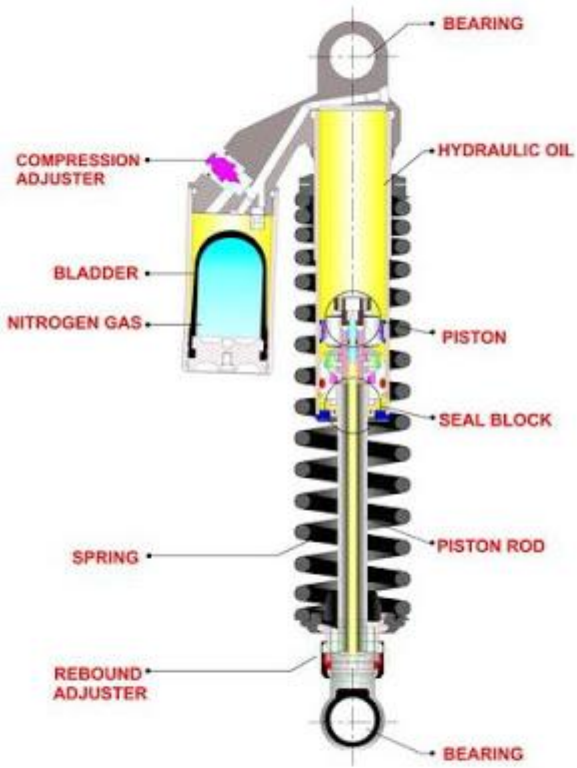


**Figure 5:** Regenerative Hydraulic Shock Absorber

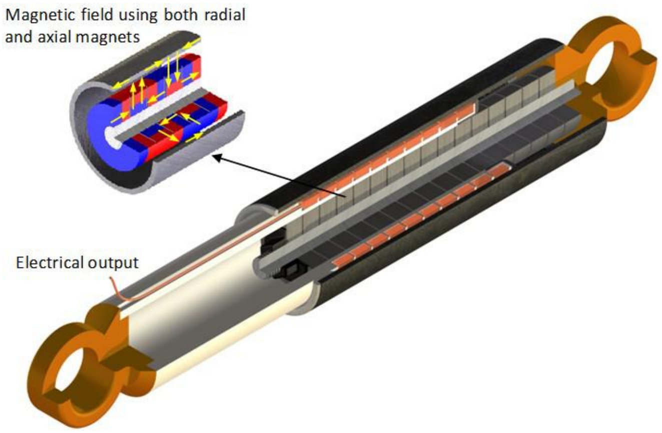


**Figure 6:** Regenerative Electromagnetic Shock Absorber

An electromagnetic linear generator and regenerative electromagnetic shock absorber is disclosed which converts variable frequency, repetitive intermittent linear displacement motion to useful electrical power. The innovative device provides for superposition of radial components of the magnetic flux density from a plurality of adjacent magnets to produce a maximum average radial magnetic flux density within a coil winding array. Due to the vector superposition of the magnetic fields and magnetic flux from a plurality of magnets, a nearly four-fold increase in magnetic flux density is achieved over conventional electromagnetic generator designs with a potential sixteen-fold increase in power generating capacity. As a regenerative shock absorber, the disclosed device is capable of converting parasitic displacement motion and vibrations encountered under normal urban driving conditions to a useful electrical energy for powering vehicles and accessories or charging batteries in electric and fossil fuel powered vehicles. The disclosed device is capable of high power generation capacity and energy conversion efficiency with minimal weight penalty for improved fuel efficiency.

## 4. Design of the Magnetic Suspension System

The design parameters used in this process are the standard values for motorcycles. The spring is mounted in between two magnets to avoid impact of magnets. The outer diameter of spring can be selected considering the clearance between casing diameter and spring which avoid jam of spring.

Outer diameter of spring,
$D_o$ = 40 mm

As per design data book for cold drawn wire steel
Wire diameter,
d = 5 mm

Inner diameter of spring,
$D_i$ = 40 - 10 = 30 mm

Calculating the load bearing capacity of spring:

For any service life,
Shear stress = 0.5 N/mm$^2$
$S_{ut}$ = 0.51190 = 595 N/mm$^2$
Spring index, C= $D_o$/d = 40/5 = 8

C = 8
Then, Wahl factor of spring,
K= (4C-1) / (4C-4) + 0.615/C

For C = 8
k= 1.18

Now to find load holding by spring P,
Shear stress = k (8PC/ (d$^2$))
P = 618.47 N
Thus spring hold the load of 618.47 N, the remaining load is absorbed by magnet.

Deflection of spring (δ) can calculate by,
δ = (8PC$^3$N) / (Gd)
δ = 56.04mm

Spring rate = P/ δ = 11N/mm
Spring stiffness = K = 11N/mm
Number of turns = N = 9

As spring has square and ground ends number of Inactive turns = 2
Total number of turn,
$N_T$ = N + 2
= 9 + 2
= 11

Solid length of spring,
$L_s$ = $N_T$ x d
= 11 x 5
= 55 mm

Free length of spring,
$L_f$ = solid length + deflection + axial gap
= 55 + 56 + 0.15(56)
= 55 + 56 + 0.15(56)
$L_f$ = 120mm
Pitch of spring = $L_f$/N = 120/9
Pitch of spring = 13.33mm

**Design of Magnet:**
Power Magnet Pair = **10,000 GP** (Gauss Power)
Weight Vehicle Body =110 Kg = 1080 N
Weight of Person Sitting On Vehicle = 140 Kg =1374 N

Total Load = Weight Vehicle Body + Weight of Person Setting On Vehicle
Total Load =1080+1374
=2454 N
Rear Suspension = 65% of 2454 N
=1595.1 N
Considering Dynamic Loads Double (W) = 1595.12 x 2
=3190.2 N
For Single Shock Absorber Weight (W/2) = 3190.1/2 = 1595.1 N

Taking Factor of Safety = 1.2

So, Design Load = (W/2) x 1.2 = 1914.92 N
Magnetic Power per Unit Area =2N/mm$^2$

So, Area Required for Suspension Of 300 Kg load
$A = 1914.12/2$
$A = 957.06\ mm^2$
$A = \pi/4 \times d^2$
$957.06 = \pi/4 \times d^2$
$d = 34.90mm \sim 35mm$
**d = 35mm**

Diameter of magnet = 35 mm

**Design of shaft**
The shaft is subjected to pure bending stress
Design force = 1914.12 N
Bending length = 165 mm
Bending moment = F L
= 1914.12 x 165
= 315829.8 N-mm
$M = (\sigma_b \pi d^3) / 32$
$315829.8 = 54.15 \times d^3$
**d = 18mm**

**Design of hollow shaft:**
M = F L
M = 1914.12 x 200
M = 382824 N-mm

$M = 2\ \sigma_b\ d^3\ (Ik^4)$
$\sigma_b = 15.893\ N/mm^2 \sim 16\ N/mm^2$
$\sigma_b = 16\ N/mm^2 < 35\ N/mm^2$
As induced stress is less than allowable stress the design of hollow cylinder is safe.
In this way, the main spring of the shock absorber is designed.

## 5. Future Scope

It is possible to do make these modification in the magnetic shock absorber, some of them are explained below:
1) If the coils are fitted at the outer side of magnet then it is possible to generate electricity which could be used for charging purposes.
2) Maglev technology could be incorporated in the motorcycles along with electromagnetic suspension system to provide for better ride on the irregular surfaces as well as on well paved roads
3) Better control of the damping could be provided by using an independent control unit for magnetic suspension.
4) Efficiency improvement can be carried out by making use of lightweight materials for the production of the suspension.

## 6. Conclusion

As we have seen the magnetic suspension is a revolutionary idea which will provide a comfortable ride by minimizing the vibrations and other factors .It would also allow to set the suspension stiffness as per requirement. Thereby magnetic suspension will be a best substitute for current problems and providing ultimate vehicle dynamics.

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