Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 5, Issue 04, April -2018

DESIGN AND DEVELOPMENT OF SUPER MAGNET SUSPENSION FOR MOTORCYCLE

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Abstract-*A suspension system is a device made for smooth out or damp shock impulse, dissolve kinetic force and jerk in a vehicle, it minimize the result of travelling on uneven earth, most important to better trip quality and amplify in comfort due to largely reduced amplitude of instability. To improve this a new adapted idea of super magnet suspension using permanent magnet and solenoid. This idea will raise road handling, soothe driving and also let us to get changeable stiffness just using magnets. The super magnet suspension has a cylindrical tubular construction having super magnet on each end. The magnetic field will be induced using solenoid winding and battery power. The arrangement will be in such a method that same poles will be facing each other resulting in repulsion of the magnets. Reducing vehicle's vibrations even as travelling on uneven roads, the magnet's repulsion will serve as dampers.*

Keywords: *Permanent Magnet; Suspension; Solenoid; Motorcycle; Vibrations.*

I. INTRODUCTION

Many devices use magnets for pulling diamagnetic materials up against gravity. It gives some natural side solidity for these types of devices. Few of them use combination of magnet and solenoid for pull and push. Magnetic levitation technology is significant because of reduction in energy use, mostly obviating friction. It avoids wear and low repairing needs too. A design of the Magnetic Shock Absorber founded on the use of magnetic property like when the same poles of two super magnets get near to each other they will repulse. This unit will mount in front axle of motorcycle. The working is very simple. Two super magnets are set in this way that one is mounted below and another is upper side. Due to same poles on same axis they repulsed from each other, when the vehicle is moving on uneven road then the gap between two magnets are reduced and shocks absorbed by repulsion property of the magnet.

II. LITERATURE REVIEW

Henter (1980) have invented that, when wheel is being urged out of alignment by side stress, there is a oppose flow of hydraulic fluid from one hydraulic-piston to other side of piston chamber and wheel remains at right angle to the longitudinal plane of rotation of the wheel (Henter & Warren, 1980). Chavan et al. (2013) researched on mono suspension system that it is easier to adjust. This mono suspension improves traveling, handling and decrease friction loss, and also explains when occupant run over a bump on a motorcycle with two shock absorbers, both the shock absorbers compress, but there is not at all a situation when both of them compress equally. It leads to downgrade dynamics when it comes to steadiness. But with a single shock absorber, this problem can be solved (Chavan, Margaje, & Chinchorkar, 2013). Dhayakar et al. (2015) have designed and analyzed on hydraulic shock absorber in which hydraulic shock absorbers with internal coil spring let front wheel to act in response to imperfection on the road while separating the rest of the vehicle from that motion. In that design only one shock to adjust, and there are no concerns about matching two shocks (Dhayakar, Vinu, Manoj, & Shanmugasundaram, 2015). Elankovan (2015) has founded that theoretical perspective and adaptation of electromagnetic system is cheaper compared to Mono-shock suspensions with batter handling and less heat loss (Elankovan, 2015). Tandel et al. (2015) have designed a fabrication of magnetic suspension. In that design of suspension a set of magnets has been selected like poles, then it is placed into in a hollow cylinder. One magnet is fixed at the top of the cylinder and other one is placed at the bottom. When they brought closer to each other they are repelled due to similar polarity and the aspect of suspension is achieved (Tandel, Desai, Desai, Shirsat, & Tambe, 2015). Bharambe (2015) has founded that a magneto rheological technology for suspension damping in which each absorber is filled with a polymer fluid containing small magnetic particles. The fluid in the absorber which converts phase from fluid to solid as the electric charge is supplied. Change in viscosity offers a variation in the damping. Each of the dampers is adjusted independently and ensures a relaxed ride along different road surfaces (Bharambe, 2016).

III. WORKING

Magnets are attracted or repelled by other magnet depending upon the location of poles. A substance that is powerfully attracted to a magnet is said to have a high permeability, unlike poles of a magnet attract each other and same poles resist each other. When two same poles sated against each other and brought nearer they will repelled. This concept is applied in this magnetic suspension design. In this suspension a set of magnets have been selected, then it is placed into in a cylinder. One magnet is fixed at the top of the cylinder and other one is placed at the bottom. When the two magnets are brought closer to each other they are repelled due to similar polarity and the aspect of suspension is achieved. These two magnets struggle in opposition to each other giving the forks move. Then arrangement of wiring is as they work as solenoid which is attached to battery. The solenoid arrangement is as it will increase magnet's power and also helps to regain magnet's power which was lost by repulsion of magnets.

IV. MATERIAL USED

Table 1 Material and their properties

Material→ Properties ↓	Grey Cast Iron	Naval Brass	Aluminium	Copper	Stainless Steel
Contains (wt %)	C (3-4) Si (1-3)	Cu (59-62) Fe (0.1) Pb (0.2) Sn (0.5-1) Zn (39.2)	Al	Cu	C (0.12) Si (0.2-1) Mn (0.5-2) Cr (18)
Density (g/cm^3)	7.250	8.450	2.700	8.900	7.850
Tensile Strength (N/mm^2)	150-400	379-607	70-670	220	420-2000
Yield Strength	50-400	172-455	25-350	75	290-1600
Melting Point (°C)	1300	950	660	1083	1510
Thermal Conductivity (W/m°C)	54.5	130	220	393.5	50.2
Magnetic Ordering	Diamagnetic	Para-Magnetic	Para-Magnetic	Para-Magnetic	Para-Magnetic
Relative Permeability	5000	0.99	1	0.99	1-7

Table 2 Properties of magnet and giron

Properties	Magnet	Giron
Relative Permeability	1.05	7000
Saturation Induction	-	2.0 Tesla
Curie Temperature	310 - 400 °C	740 °C
Remanence	1.4 Tesla	-
Density	7.3 - 7.5 g/cm^3	3.5 g/cm^3

V. DESIGN

Design of Magnet (Nd Fe B)

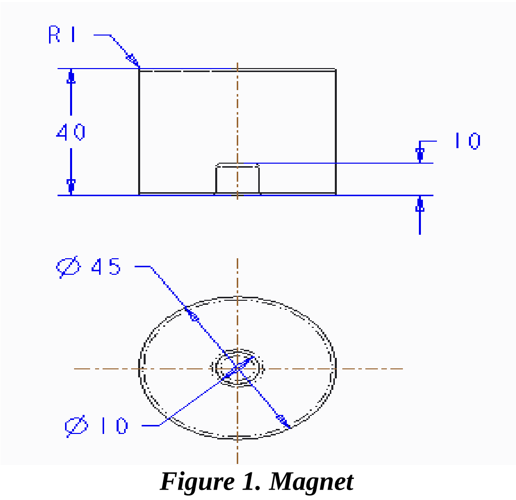

Figure 1. Magnet

Power of magnet pair (**B**) = 14400 Gauss Power
Diameter of magnet = 45 mm
Height of magnet = 40 mm
Now using solenoid with 3 cord of 1 mm coated copper wire
1 mm copper wire can carry 3A of current and 3 cord of 1 mm wire can carry 3 times of current so it will be 3×3 = 9A

Now calculation for upper side of solenoid power
Solenoid diameter **d** = 60 mm
Solenoid length **L** = 190 mm
Voltage **V** = 12 V
No. of turns **N** = 400
Area of copper wire $\mathbf{a} = \pi \times r^2$ ……. **(1)**
$= \pi \times 0.1 \times 0.1$
$= 0.785\ mm^2$
Now length of wire $\mathbf{l} = \pi \times d \times N$ ……. **(2)**
$= 75398$
≈ 75400 mm
Resistance $\mathbf{R} = (\rho \times l) / a$ ……. **(3)**
$= (1.7 \times 10^{-5} \times 75400) / 0.785$
$= 1.63\ \Omega$
Now current $\mathbf{I} = V / R$ ……. **(4)**
$= 7.36$ A
7.36 A < 9A so solenoid can be used with 3 cord wire of 1 mm diameter
Now produced magnetic field power by solenoid (**B_1**)
$\mathbf{B_1} = (\mu \times N \times I) / L$ ……. **(5)**
$= (4 \times \pi \times 10^{-4} \times 400 \times 7.36) / 190$
$= 0.0194$ Tesla
$= 194$ gauss
Now total magnetic force for upper side of solenoid (**B_u**)
$\mathbf{B_u} = B_1 + B$ ……. **(6)**
$= 194 + 14400$
$= 14594$ gauss
$= 1.45$ T
Now calculation for down side of solenoid
Solenoid diameter **d** = 60 mm
Solenoid length **L** = 69 mm
Voltage **V** = 12 V
No. of turns **N** = 350 turns
From equation (1)
Area of copper wire $\mathbf{a} = \pi \times r^2$
$= \pi \times 0.1 \times 0.1$
$= 0.785\ mm^2$
From equation (2)
Now length of wire $\mathbf{l} = \pi \times d \times N$
$= 65973.4$
≈ 65975 mm
From equation (3)
Resistance $\mathbf{R} = \rho \times l / a$
$= (1.7 \times 10^{-5} \times 65975) / 0.785$
$= 1.42\ \Omega$
From equation (4)
Now current $\mathbf{I} = V / R$
$= 8.45$ A
8.45 A < 9A so solenoid can be use with 3 cord wire of 1 mm diameter
Now produced magnetic field power by solenoid (**B_2**)
$\mathbf{B_2} = (\mu \times N \times I) / L$ ……. **(7)**
$= (4 \times \pi \times 10^{-4} \times 350 \times 8.45) / 69$
$= 0.0538$ T (Tesla)
$= 538$ gauss
Now total magnetic force for down side of solenoid (**B_d**)
$\mathbf{B_d} = B_2 + B$ ……. **(8)**
$= 538 + 14400$
$= 14939$ gauss
≈ 1.5 T
In this suspension air gap between magnets is 150 mm
According to law of magnetic force
Force $\mathbf{F} = (B_u \times B_d) / 4 \times \pi \times \mu \times r^2$, **N** ……. **(9)**
Where, B_u = upper side magnet's magnetic strength, gauss

B_d = down side magnet's magnetic strength, gauss
μ = absolute permeability (for air its 1)
r = distance between two poles, mm

From equation (9), Table 3 shows different forces at different distance of magnetic poles.

Table 3. Different force at different distance of magnetic poles

Sr. no.	B_u (gauss)	B_d (gauss)	r (mm)	r^2 (mm^2)	Deflection (mm)	Force (N)
1	14594	14939	150	22500	0	772.6
2	14594	14939	140	19600	10	887.0
3	14594	14939	130	16900	20	1028.7
4	14594	14939	120	14400	30	1207.3
5	14594	14939	110	12100	40	1436.8
6	14594	14939	100	10000	50	1738.5
7	14594	14939	90	8100	60	2146.3
8	14594	14939	80	6400	70	2716.4
9	14594	14939	70	4900	80	3540
10	14594	14939	60	3600	90	4820
11	14594	14939	50	2500	100	6940

Calculation for loads on hydraulic suspension

Weight of vehicle body = 135 kg = 1323 N
Weight of person sitting on vehicle = 150 kg = 1470 N
Total load = Weight of vehicle body + Weight of person sitting on vehicle
Total load = 1323 + 1470 = 2793 N
Front Suspension = 35% of total weight = 978 N
Considering dynamic loads doubled (W) = 1956 N
For single shock absorber weight = W / 2 = 978 N
Taking FOS = 1.5
So design load on single front suspension = 1467 N

1467 N force can be used for magnet because at distance 100 mm of air gap force will be 1738.5 N in magnetic suspension and deflection will be 50 mm.

Design of Rod (Stainless Steel)

The rod is subject to pure bending stress

So $\sigma_b = (32 \times M_b) / \pi \times D^3$ .... **(10)**

Where, σ_b = Bending stress of rod
M_b = Bending moment
D = Diameter of rod

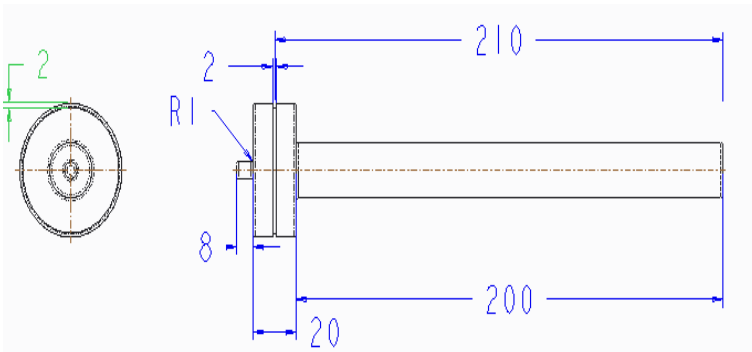

Figure 2. Rod

Design force = 1467 N
Bending length = 200 mm
Bending moment = F × L
Bending moment = 1467 × 200 = 293400 N–mm
From equation (9)
Diameter of rod $D^3 = (32 \times M_b) / \sigma_b \times \pi$
So D = 12.67 mm ≈ 13 mm
Now maximum force occur about 1738.5 to 2146.3 N
So taking average of them force = 1943 N
Now bending moment will be 388600 N-mm

Therefore diameter of rod will be 13.84 mm ≈ 14mm
Here taking diameter of rod is 20 mm
According to diameter of magnet taking diameter of rod head = 47 mm
And consider thickness of rod head = 20 mm

Design of Rod Head Ring (Cast Iron)
Inner diameter of ring = 45 mm
Outer diameter of ring = 49 mm
Thickness of ring = 2 mm

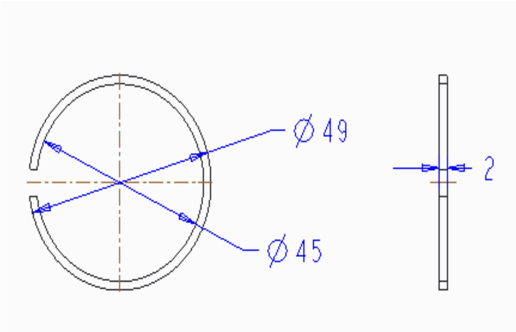

Figure 3. Rod head ring

Design of Brass Cylinder (Naval Brass Cylinder)
There will be friction occurs between road head ring and brass cylinder and that value can be negligible but as matter of fact taken thickness of brass cylinder is 2 mm
So according to road head ring outer diameter,
Inner diameter of brass cylinder = Outer diameter of rod head ring = 49 mm
Outer diameter of brass cylinder = 53 mm

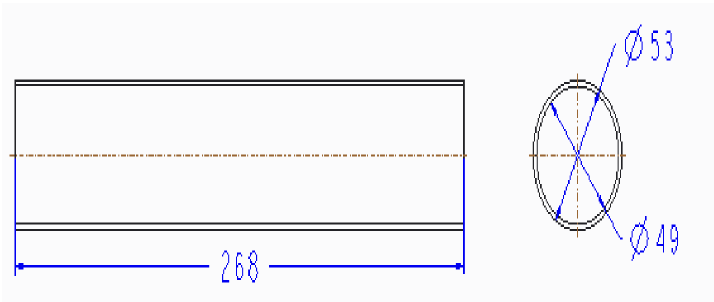

Figure 4. Brass cylinder

Thickness = 2 mm
Length of brass cylinder = 268 mm
Design of Solenoid Cylinder (Aluminium and Copper Wire)

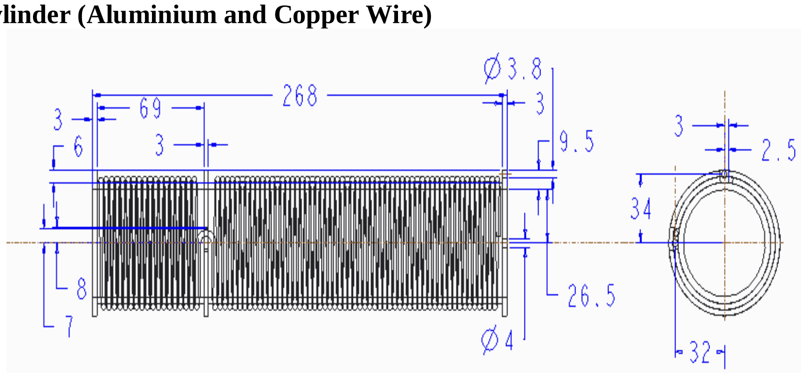

Figure 5. Solenoid cylinder

Internal diameter of solenoid cylinder = outer diameter of brass cylinder = 53 mm
Taking wall thickness of solenoid cylinder = 3.5 mm
So outer diameter of solenoid cylinder will be 60 mm
Length of solenoid cylinder = 268 mm
Vertical aluminum strip = 6 mm (only for winding copper wire)
Thickness of strip = 3 mm (only for winding copper wire)

Design of Giron Cylinder (Giron)
Here outer diameter of solenoid cylinder (with strip) will be inner diameter of giron cylinder
So inner diameter of giron cylinder = 72 mm
Thickness of giron cylinder taking as 2 mm
So outer diameter of giron cylinder =76 mm
Length of giron cylinder = 268 mm

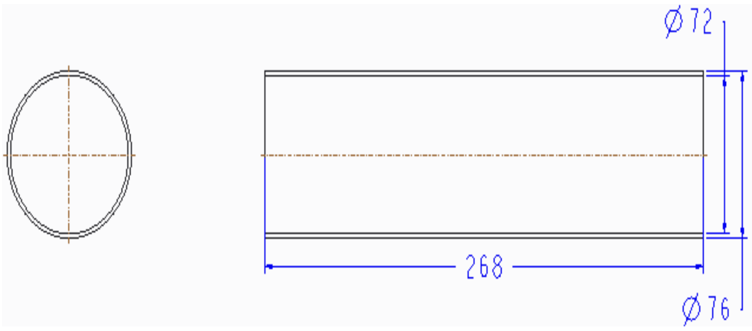

Figure 6. Giron cylinder

Design of Casing Cylinder (Grey Cast Iron)
Outer diameter of giron cylinder will be inner diameter of casing cylinder = 76 mm
Thickness of casing cylinder = 4 mm (Ebrahimi, 2009).
Outer diameter of casing cylinder = 84 mm
Top side of thickness of casing cylinder = 8 mm

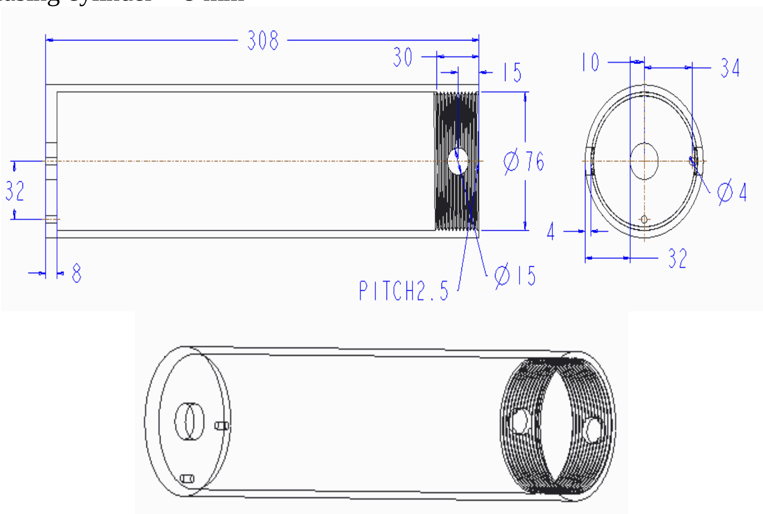

Figure 7. Casing cylinder

Length of casing cylinder = 308 mm
Bore depth of casing cylinder = 300 mm
Axle pin diameter 15 mm (it can be varies according to axle pin)
There will be no failure of thread cause of axle load and axle pin is inserted through pin hole.
External Threaded Nut (Grey Cast Iron)

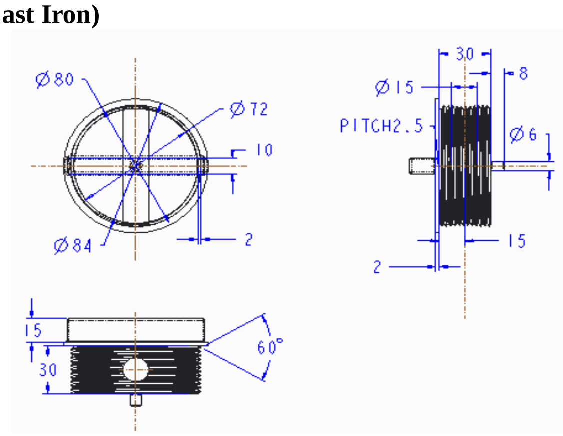

Figure 8. External threaded nut

Major diameter = 76 mm
Minor diameter = 72 mm
Pitch = 2.5
Thread length = 30 mm
Hole diameter in nut = 15 mm
α = 30°

Giron Plate (Giron)

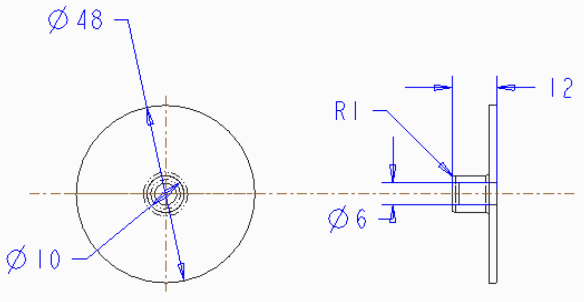

Figure 9. Giron plate

thickness of plate = 2 mm
Diameter of plate = 48 mm
Bore depth in plate = 8 mm

Rubber Spring
Inner diameter of rubber spring = 20 mm
Inner diameter of rubber spring = 20 mm
Outer diameter of rubber spring = Major thread diameter = 45 mm
Minor thread diameter = 41 mm
Pitch = 2.5
α = 30°

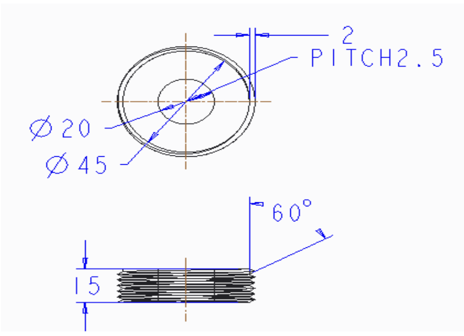

Figure 10. Rubber spring

VI. PARTS AND DIMENSIONS

Table 4. Parts and their dimensions

Parts	Length (mm)	Diameter (mm)	Pitch	Thread Length (mm)	Thickness (mm)	Bore Diameter (mm)	Bore Depth (mm)	Strip (mm)
Magnet	-	45	-	-	40	10		-
Rod	200	20	-	-	-	-		-
Rod Head		47	-	-	20	-		-
Rod Head Ring	2	Inner = 45 Outer = 49	-	-	2	-		-
Giron Cylinder	268	Inner = 72 Outer = 76	-	-	2	-		-
Giron Plate	-	48			2	6	8	-
Casing	308	Inner = 76 Outer = 84	2.5	30	4	-	300	-
External Threaded Nut	55	Major = 76 Minor = 72	2.5	30	30	-	-	-
Solenoid	268	Inner = 53	-	-	3.5	-	-	T = 3

Cylinder		Outer = 60						H = 6
Rubber Spring	-	Major = 45 Minor = 41	2.5	15	15	20	15	-
Brass Cylinder	268	Inner = 49 Outer = 53	-	-	2	-	-	-
Copper Wire	141375	1 (3 cords)	-	-	-	-	-	-

Table 4 shows the dimensions of parts which are used in design.

VII. ARRANGEMENT OF SUSPENSION

The arrangement of this suspension is such a way that in casing first placed a giron cylinder which is a fine and effective shield against magnet and its field. Then inside that giron cylinder solenoid cylinder is placed which is winded with 3 cord of 1 mm diameter of copper wire. In this cylinder the winding of wire is such that after distance of 190 mm, the direction of winding will change from clockwise to anticlockwise or vice versa. The reason behind this method is to provide more magnetic power from solenoid winding and also help to maintain super magnet's power. After solenoid cylinder naval brass cylinder is inserted which have high resistance against wear also its diamagnetic material which will not attract by magnets. Then rubber spring is inserted in naval brass cylinder then rod is inserted on which giron plat and magnet is attached. Then after external threaded nut is tightened on which giron plate and magnet is attached.

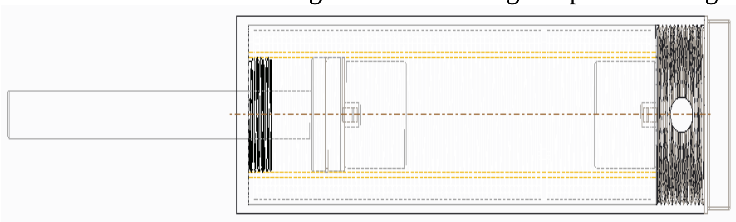

Figure 11. Fully arranged suspension

VIII. CONCLUSION

From above analysis it can be said that, this design occupy less space than other electromagnetic suspension because of giron shield. It also offers batter performance without using any type of fluid or damping material. Also it consumes less power.

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