DESIGN AND ANALYSIS OF MAGNETIC SUSPENSION SYSTEM

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Abstract - The vehicle suspension system is responsible for driving comfort and safety, as the suspension carries the vehicle body and transmit all forces between the body and the road. This paper details about the magnetic suspension system where two or more magnets are used. This paper describes the design and construction of a prototype magnetic suspension system. The first magnet is placed at the top of the inner portion of the cylinder. The second magnet is attached to the strut which is suspended in the inner middle portion of the cylinder and reciprocates up and down due to repulsion. The third magnet is placed at the bottom of the inner part of cylinder. These magnets repels each other and thus suspension is achieved.

Key Words: Suspension, Magnet, Strut, Cylinder,Design

1.INTRODUCTION

The suspension system of a vehicle refers to the group of mechanical components that connect the wheels to the frame or body. A great deal of engineering effort has gone into the design of suspension systems because of an unending effort to improve vehicle ride and handling along with passenger safety and comfort. In the horse and buggy days, the suspension system consisted merely of a beam (axle) that extended across the width of the vehicle. In the front, the wheels were mounted to the axle ends and the axle was rotated at the center to provide steering. The early automobiles used the one-piece axle design but instead of being rotated at the center, it was fix-mounted to the vehicle through springs to provide the cushioning of shock loads from road inaccuracies. The wheels were rotationally-mounted at the axle ends to provide steering. The first springs consisted of thin layers of narrow pieces of strip steel stacked together in an elliptical shape and were called leaf springs. In later installations, leaf springs were replaced by coil springs. In front-engine rear-drive vehicles, the front beam axle was replaced by independently mounted steerable wheels. The wheels were supported by short upper and lower hinged arms holding them perpendicular to the road as did the previous axle beam designs. A coil spring was used to support either the upper or the lower arm to provide dampening. Shock absorbers began to be used to dampen shock loads and also to provide resistance to spring oscillations. Later it was learned by shortening the upper arm; wheel tilt (camber) could be controlled to prevent edge loading tires while cornering. The power transmitting drive axle in the rear served as the beam-type suspension with dampening provided by either leaf or coil springs as well as shock absorbers.
When front-engine front-drive passenger cars were introduced, the upper arm was rotated up and replaced by a member called a "strut" which contained the concentrically mounted spring and shock. This arrangement provided additional space for transverse mounted engine/transmission modules and the front drive shaft. This same type of suspension was also used in the rear of many cars..

1.1 Problem Statement:

Now-a-days, shock absorption in a vehicle is mainly done with the help of springs.As we know the disadvantages of our conventional suspension system and in order to overcome the disadvantages, the magnetic suspension system can be a option to the same. Therefore the magnetic suspension system can be used in many applications of the suspension in automobile industries and in other industries. Here we will focus on developing the magnetic suspension systems using a permanent magnet.

1.2 Objectives:

I).To prevent the roadshocks from being transmitted to the vehicle.
II).To increase the overall stability of vehicle.
III).To maintain good cushioning effect.

2. MAGNETIC SUSPENSION SYSTEM

2.1 Operating Principle:

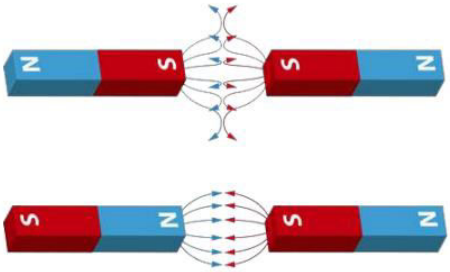

Fig-1: Working principle

We know that unlike poles of a magnet attract each other and like poles repel each other which is shown in fig 1. When we place two south poles or north poles facing each other and when they are brought closer, they are repelled. This concept is used to design the magnetic suspension system. One magnet is placed at the bottom portion of the cylinder. The other one is fixed to the strut which is connected to the chassis on one end. When the two magnets are brought closed to each other, they are repelled due to similar polarity and the aspect of suspension is achieved.

2.2 Construction:

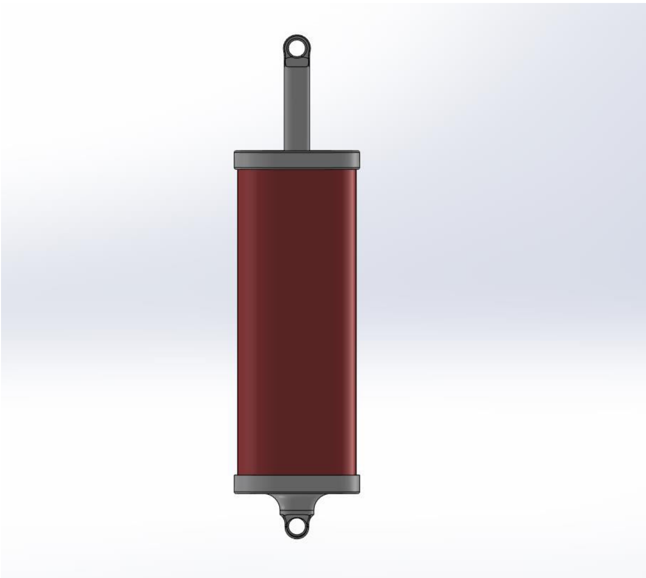

Fig-2: Magnetic Suspension System

The magnetic suspension system is shown in fig 2. The main parts of the system are:-
1)Solid shaft
2)Hollow shaft
3)Magnets

2.3 Working:

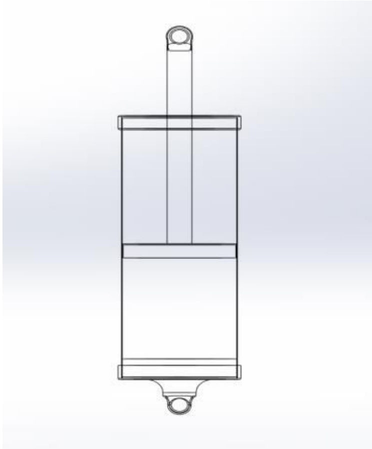

Fig-3: Working

The two disc magnets in a tube or two ring magnets on a shaft, as seen in above figure comprise our required magnet for motorcycle front suspension system. With unlike poles facing, the magnets repel each other and generate an air gap between them. The repulsive force restores displacement towards each other, and displacement away is restored by gravity. We have a set of shocks with magnets inside them that are used as the fork setup. There is one magnet at the top of the inner portion of the shock with the north polarity facing down towards the ground. The second magnet sits on top of the inner shock that pivots up and down. This magnet has the north polarity upwards so it's parallel with the other magnet. The two magnets fight against each other giving the forks travel. There is also an adjustment at the top of the shock, which allows the magnets to become closer, together for a stiffer travel or further apart for softer travel.

3. MACHINE ELEMENTS

3.1 Solid and Hollow Shaft:

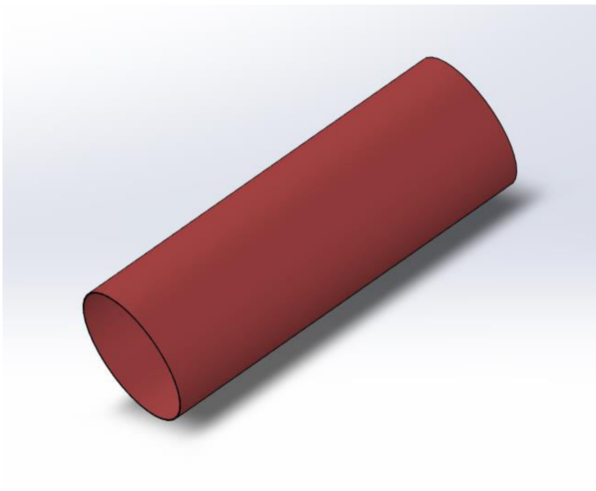

Fig-4: Solid and Hollow Shaft.

The shaft is a material which is made of mild steel. The shaft is the outer covering of the magnetic suspension system. The length of the shaft is 200mm.

3.2 Magnets:

The magnet's material is made of neodymium. We have employed two magnets in the system. The diameter of the magnet is 40mm.

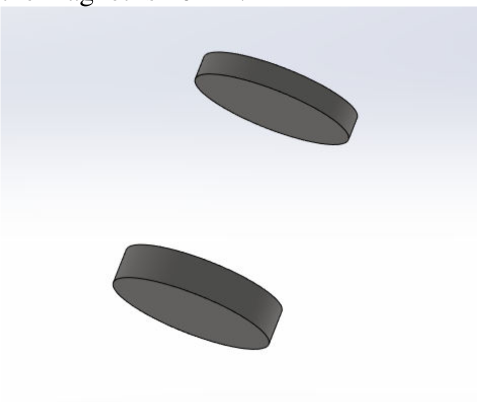

Fig-5: Magnets

4. DESIGN CALCULATIONS

4.1 Design of magnet:

4.1.1 Material Selection:

Neodymium (NdFeB): It is a permanent rare-earth magnet which is made from Neodymium, Iron and Boron. It is also the most powerful magnet used commercially. Table 1 shows the details of magnetic materials with its range of temperatures in oC and oF.

Magnet	B_r (T)	H_{ci} (kA/m)	BH_{max} (kJ/m^3)	T_C	
				(°C)	(°F)
$Nd_2Fe_{14}B$ (sintered)	1.0–1.4	750–2000	200–440	310–400	590–752
$Nd_2Fe_{14}B$ (bonded)	0.6–0.7	600–1200	60–100	310–400	590–752
$SmCo_5$ (sintered)	0.8–1.1	600–2000	120–200	720	1328
Sm(Co, Fe, Cu, Zr)$_7$ (sintered)	0.9–1.15	450–1300	150–240	800	1472
Alnico (sintered)	0.6–1.4	275	10–88	700–860	1292–1580
Sr-ferrite (sintered)	0.2–0.78	100–300	10–40	450	842

As it is evident from the table above, Neodymium magnets have:
1) Higher **Remanence** (**Br**: which measures the strength of the magnetic field)
2) Higher **Coercivity** (**Hci**: the material's resistance to becoming demagnetized)
3) Higher **Energy product** (**BHmax**: the density of magnetic energy)
Also, Neodymium magnets are graded according to the above mentioned properties:
1) N35-N52
2) N33M-N48M
3) N30H-N45H
4) N30SH-N42SH
5) N30UH-N35UH
6) N28EH-N35EH
N52 magnets are the strongest and most optimum for our usage.

4.1.2 Design Calculation:

Power of magnet pair = 10000 Gauss power
Weight of vehicle body= 170 kg = 1667 N
Weight of person sitting on vehicle = 150 kg = 1471 N
Total load = Weight of vehicle body + Weight of person sitting on vehicle
= 1667 N + 1471 N
= **3139 N**
Weight on Suspension:
65% of the weight can be carried by the suspensions therefore the total weight on suspensions are:
65% x 3139 N = 2040 N
Therefore weight carried by one suspension rod will be:
2040/2 = 1020 N
Taking F.O.S = 1.2
Therefore total load = 1.2 x 1020 N
= 1224 N
Magnetic Power per unit Area = 2 N/mm2
Therefore Area required for a total load of 688 N is:
Area = Load/Magnetic power
= 1224/2
= 612 mm2
Area = (π/4) x D2
D2 = Area x (4/π)
D = (612 x (4/π))1/2
= 40.14 mm
Approximate diameter of magnet= **40 mm.**

4.2 Design of Solid Shaft:

4.2.1 Material Selection:

Steel is a metal composed of iron and carbon in varying composition. Mild steel is a component which is made of 0.05 to 0.25% carbon. It is preferred over other materials because:
I) It is readily available.
II)It is much cheaper than its competitors such as stainless steel.
III) Available in standard sizes.
IV) Good mechanical properties
V) Moderate factor of safety; a high factor of safety results in unnecessary wastage of material and a low factor of safety might make the operation risky, hence increasing the chances of failure.

VI) It has a low co-efficient of thermal expansion.

4.2.2 Design Calculation:

The shaft is subject to pure bending stress
Design force = 2040 N
Bending length = 200 mm
Bending moment = F x L
Bending moment = 2040 x 200
= 408096 N-mm
M = π /32 x Fb x d3
408096 = π /32 x 865 x d3
d = 16.875 mm
Approximate Diameter is **17 mm**

4.3 Design of hollow Shaft

4.3.1 Material Selection:

Steel is a metal composed of iron and carbon in varying composition. Mild steel is a component which is made of 0.05 to 0.25% carbon. It is preferred over other materials because:
I) It is readily available.
II) It is much cheaper than its competitors such as stainless steel.
III)Available in standard sizes.
IV) Good mechanical properties
V) Moderate factor of safety; a high factor of safety results in unnecessary wastage of material and a low factor of safety might make the operation risky, hence increasing the chances of failure.
VI) It has a low co-efficient of thermal expansion.

4.3.2 Design Calculation:

Taking Inner Diameter as 23 mm.
Fb = 20-35 N/mm2
Bending moment (M)= 408096 N –mm
M = π /32 x Fb x (D3 – d3)
408096 = π /32 x 20 x (D3 – 16.875)
D1 = 69.68 mm
M = π /32 x Fb x (D3 – d3)
408096 = π /32 x 35 x (D3 – 16.875)
D2 = 59.80 mm

Hence the range of the outer diameter can be from **60-70 mm**

5. FEA ANALYSIS

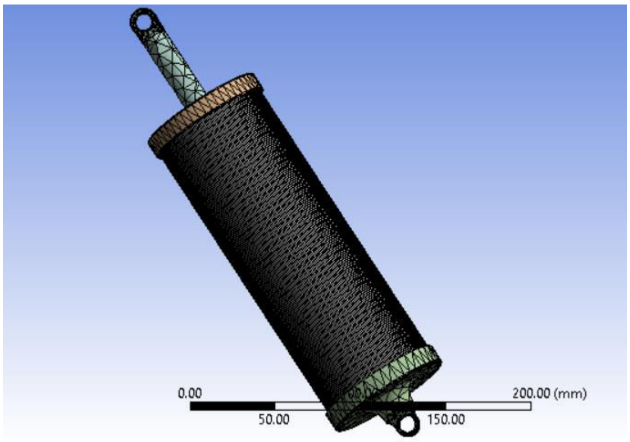

Fig-6: Meshing

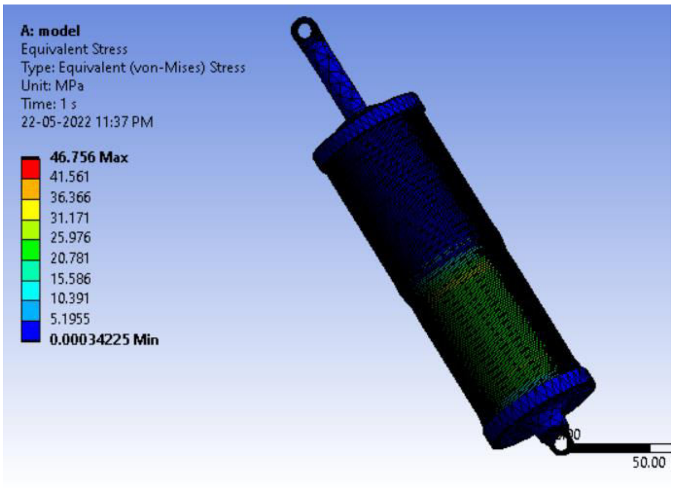

Fig-7: Equivalent(von-Mises) Stress

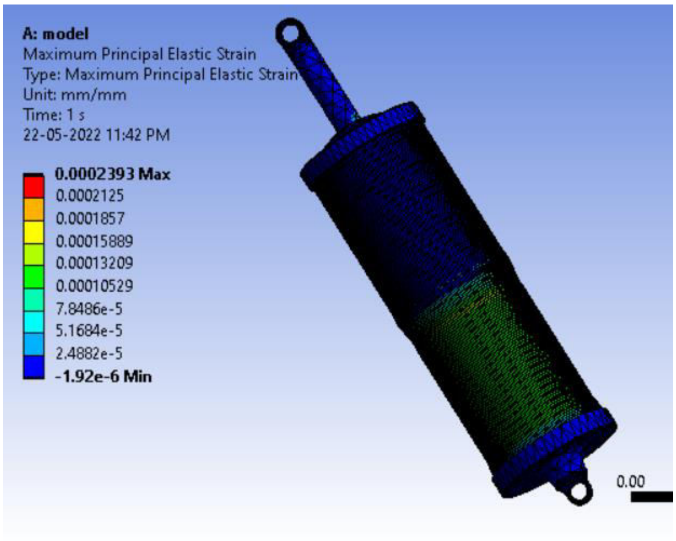

Fig-8: Maximum Principal Elastic Strain

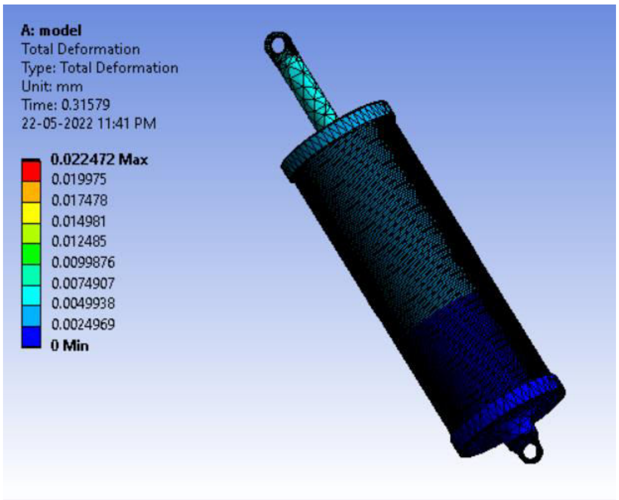

Fig-9: Total Deformation

6. 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.

7. CONCLUSION

Due to change in the vehicle concepts from internal combustion (IC) to the electric car, the suspension system becomes ever more important due to the changes in sprung and unsprung masses. Active magnetic suspension systems can maintain the required stability and comfort due to the ability of adaptation in correspondence with the state of the vehicle. Magnetic suspension system mainly summarized the use of permanent magnets in order to overcome the disadvantages of conventional suspension systems and can used as an option in place of conventional suspension systems. This model of the suspension system has a higher working life than the coil spring system. The latter is exposed to various atmospheric effects such as corrosion which decreases its working life. The design calculations suggest optimum dimensions required for the proposed prototype taking into consideration the type of material used.

8. REFERENCES

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