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DESIGN OF MAGNETIC SUSPENSION SYSTEM FOR BICYCLE

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ABSTRACT

The vehicle suspension system is responsible for driving comfort and safety, as the suspension caries the vehicle body and transmit all forces between body and the road. The vehicle suspension system consists of wishbones, the springs and the shock absorber to transmit and absorb filter all forces between body and road. The spring carries the body mass and isolates the body from road disturbances and thus contributes to drive comfort. Driving comfort results from keeping the physiological stress that the vehicle occupants are subjected by vibration, noise and climatic conditions down to as low a level as possible. This paper outlines the magnetic suspension where two or more magnets of the same polarity absorb all bumps. The design and analysis for fork suspension of bicycle using magnetic suspension system is discussed. This paper describes the design, construction, and testing of a prototype magnetic suspension system. There is one magnet fixed at the top of the inner portion of the cylinder. The second magnet is fixed on a strut and is suspended in the middle inner portion of cylinder and reciprocates up and down due to repulsion. The third magnet is placed at the bottom of the cylinder on the inner side and it repels the second magnet on speed breakers. These magnets repel each other to achieve the aspect of suspension.

Keywords: Automobile, Coil Suspension, Leaf spring Suspension, Magnetic Suspension,Vehicle Suspension System.

I. INTRODUCTION

The complete suspension is to absorb the vehicle body from road shocks and vibrations otherwise it is transferred to the passengers and load. It must keep the tires in contact with the road, regardless of road surface. A basic suspension system consists of the parts springs, axles, shock absorbers, arms rods and ball joints. . Light commercial vehicles have heavier springs than passenger vehicles, and can have coil springs at the front and leaf springs at the rear. Each side of the vehicle wheels connected by solid or beam, axles. Then the movement of a wheel on one side of the vehicle is transferred to the other wheel with independent suspension, the wheel can move independently of each other, which reduce body movement. And it is also prevents the other wheel being affected by movement of the wheel on the opposite side and reduces body movement.

K Pavan Kumar et.al. (2013) discussed about the static analysis of primary suspension system, their work is carried out on modeling helical spring in Pro/E and analysis in ANSYS of primary suspension spring with two materials Chrome Vanadium is a existing material and 60Si2MnA steel is a new material, the conventional steel helical spring 60Si2MnA is proved as best material for helical spring by reduction of deflection and overall stress. Priyanka Ghate et al. investigated the failure of A Freight Locomotive helical spring by redesigning to improve the durability and ride index in this the composite suspension system can sustain the loads in under normal operation conditions and maintains the ride index but the failure occurs during cornering and hunting speeds to avoid this the study of dynamic behaviour of a composite spring is analysed. Mehdi Bakhshesh et al.(2012) worked on optimum design of steel helical spring related to light vehicle suspension system under the effect of a uniform loading has been studied and finite element analysis has been compared with analytical solution. N.K.Mukhopadhyay et.al (2006), investigation on the premature failure of suspension coil spring of a passenger car, which failed during the service within few months and identified the reasons for the failure. This investigation micro structural analysis, SEM analysis, hardness testing, and chemical analysis. S.S.Gaikwad et.al (2013),examined on Static Analysis of Helical Compression Spring Used in Two-Wheeler Horn, using NASTRAN solver and compared with analytical results .Static analysis determines the safe stress and corresponding pay load of the helical compression spring. it is concluded that the maximum safe pay load for the given specification of the helical compression spring is 4 N. At lower loads both theoretical and NASTRAN results are very close, but when load increases the NASTRAN results are uniformly reduced compared to theoretical results.

In today’s world, the conveyance sector has reached its peak. As the world is progressing new technologies are invented. Each part of an automobile is improving day-by-day as well as replacing obsolete parts. In two wheelers, the suspension system used is a coil spring but there are certain limitations to it. After a period of time it not only becomes harder but also reduces the cushioning effect. This limitation is overcome by magnetic suspension. The cushioning effect provided by magnetic suspension exists for a longer time. Magnetic suspension system is mainly based on the property of magnets that like poles of magnets repel each other. The two magnets fight against each other to achieve the aspect of suspension. This characteristic of magnets is used for suspension work of system.

In the first part of the paper we have suggested the objectives of suspensions, second, third and fourth part shows the objective of suspension, use of technology and concept of magnetic suspension. Material selection and design is discussed in the fifth and sixth part of the paper. Catia model for magnetic suspension assembly, magnet assembly shown in the seventh part of the paper.Comparison of magnetic shock absorber with spring shock absorber, conclusion and references are given in eighth, ninth and tenth part of the paper.

II. OBJECTIVES OF SUSPENSION

- To maintain good cushioning effect.
- To eliminate the road shocks from being transmitted to the vehicle and its components.
- To safeguard the occupants of vehicle from road bumps
- To control the maintenance as well as initial cost

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- To maintain the stability of vehicles
- To give the good road holding while driving, cornering and braking.
- To validate the design by testing prototype model.

III. TECHNOLOGY

Magnets are attracted or repelled by other materials depending upon the position of poles. A material that is strongly attracted to a magnet is said to have high permeability. Iron and steel are two examples of materials with very high permeability and they are strongly attracted to magnets. It is based on a simple concept that when two magnets of same polarity are brought together they repel each other due their magnetic field. The SI unit of magnetic field strength is the Tesla, and the SI unit of total magnetic flux is the Weber. 1 Tesla = 1000 gauss = 1weber/m^2.

IV. CONCEPT

Unlike poles of a magnet attract each other and like poles repel each other as shown in figure 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 in magnetic suspension. One magnet is fixed at the top of the inner portion of the cylinder. One is placed at the bottom and another is fixed to a strut which is connected to the chassis on one end and freely suspended in the magnetic field between the two fixed magnets. When the two magnets are brought closer to each other they are repelled due to similar polarity and the aspect of suspension is achieved. There is one magnet at the top of the inner portion of the cylindrical shock sleeve with the north polarity facing down towards the ground. The second magnet sits on the bottom of the cylinder. This magnet has the south polarity upwards so it's parallel with the other magnet. The third magnet which is fixed on the strut, has its north polarity faced upwards and south polarity faced downwards. The three magnets fight against each other giving the forks travel.

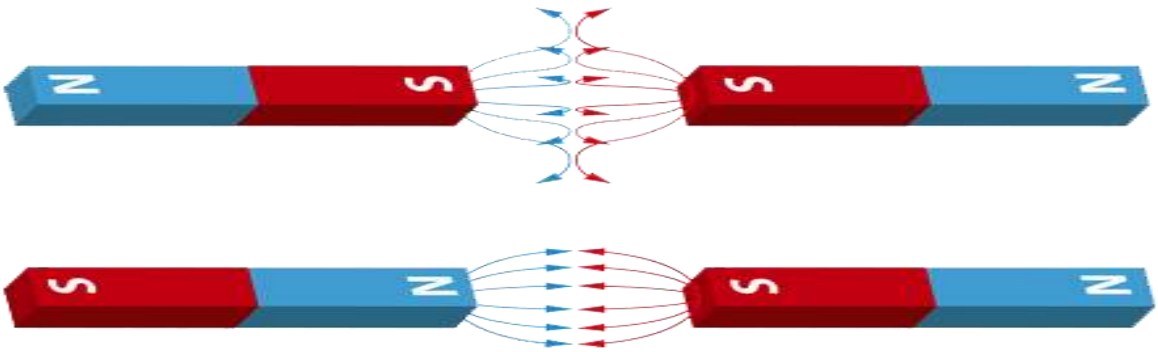

Fig.1: Magnetic Properties

V. SELECTION OF MATERIALS

Selection of the material to be used to fabricate different components of the system is an important step from the design perspective. Different materials have different properties such as modulus of elasticity, tensile &

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compressive stresses and shear stress. Hence it is important to select materials which not only fit the profile from dimensional and environmental factors (corrosion), but also from an economic factor.

5.1 Material used for Magnets:

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 °C and °F.

Table 1: Magnetic Materials(K Pavan Kumar et.al 2013)

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:

- Higher **Remanence** (**B_r:** which measures the strength of the magnetic field)
- Higher **Coercivity** (**H_{ci}:** the material's resistance to becoming demagnetized)
- Higher **Energy product** (**BH_{max}:** the density of magnetic energy)

Also, Neodymium magnets are graded according to the above mentioned properties:

- N35-N52
- N33M-N48M
- N30H-N45H
- N30SH-N42SH
- N30UH-N35UH
- N28EH-N35EH

N52 magnets are the strongest and most optimum for our usage.

5.2 Material for Shafts

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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:

- It is readily available.
- It is much cheaper than its competitors such as stainless steel.
- Available in standard sizes.
- Good mechanical properties
- 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.
- It has a low co-efficient of thermal expansion.

VI. DESIGN

6.1 Design of Magnets

Power of magnet pair = 10000 Gauss power

Weight of vehicle body= 30 kg = 294 N

Weight of person sitting on vehicle = 150 kg = 1471 N

Total load = Weight of vehicle body + Weight of person sitting on vehicle

= 294 N + 1471 N

= **1765 N**

Weight on Suspension:

65% of the weight can be carried by the suspensions therefore the total weight on suspensions are:

65% x 1765 N = 1148 N

Therefore weight carried by one suspension rod will be:

1148/2 = 574 N

Taking F.O.S = 1.2

Therefore total load = 688 N

Magnetic Power per unit Area = 2 N/mm^2

Therefore Area required for a total load of 688 N is:

Area = Load/Magnetic power

= 688/2

= 344 mm^2

Area = $(\pi/4) \times D^2$

D^2 = Area x $(4/\pi)$

D = $(344 \times (4/\pi))^{1/2}$

= 20.91 mm

Approximate diameter = **21 mm**

6.2 Design of Solid Shaft:

The shaft is subject to pure bending stress Design force = 1148 N
Bending length = 165 mm

Bending moment = F x L

Bending moment = 1148 x 165 = 189420 N –mm

$M = \pi /32 \times F_b \times d^3$

$189420 = \pi /32 \times 865 \times d^3$

d = 13.068 mm

Approximate Diameter is **13 mm**

6.3 Design of hollow shaft:

Taking Inner Diameter 23 mm.

$F_b = 20\text{-}35\ N/mm^2$

Bending moment (M)= 1148 x 165 = 189420 N –mm

$M = \pi /32 \times F_b \times (D^3 – d^3)$

$189420 = \pi /32 \times 20 \times (D^3 – 25^3)$

D = 47 mm

$M = \pi /32 \times F_b \times (D^3 – d^3)$

$189420 = \pi /32 \times 35 \times (D^3 – 25^3)$

D = 40 mm

Hence the range of the outer diameter can be from **40-47 mm**

VII. DRAWING OF MAGNETIC SUSPENSION USING CATIA MODEL

Catia offers a range of tools to enable the generation of a complete digital representation of the product being designed. In addition to the general geometry tools there is also the ability to generate geometry of other integrated design disciplines such as industrial and standard pipe work and complete wiring definitions. Catia also available to support collaborative development. A number of concept design tools that provide up-front Industrial Design concepts can then be used in the downstream process of engineering the product. These range from conceptual Industrial design sketches, reverse engineering with point cloud data and comprehensive freeform surface tools. Figure number 2 to figure number 8 shows the various drawing of the magnetic suspension.

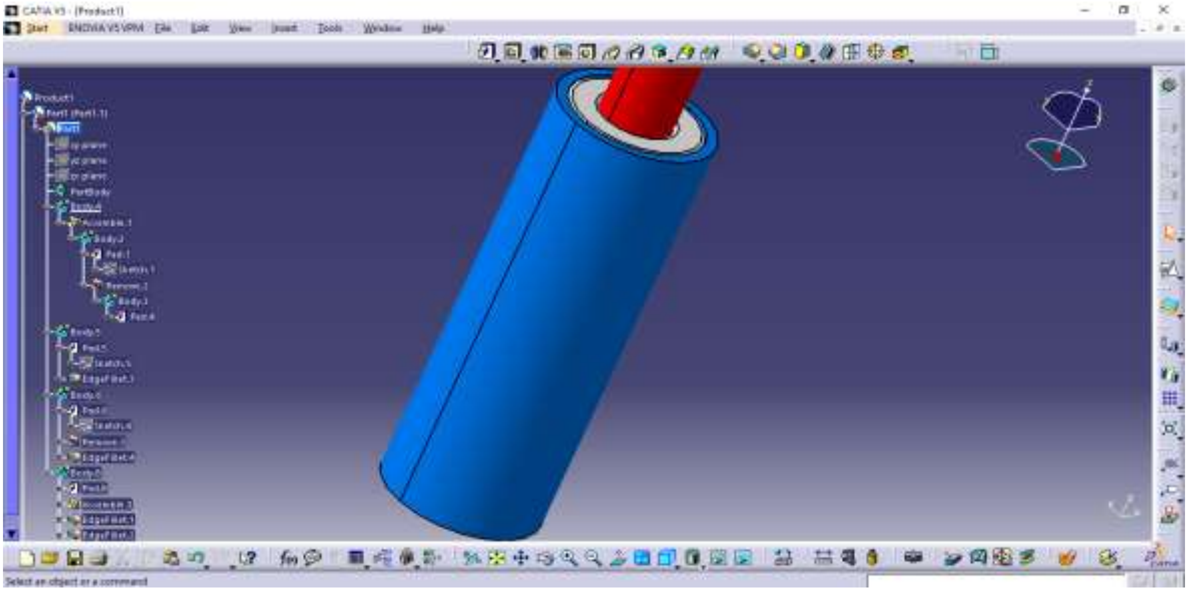

Fig.2:CATIA Model of Magnetic Suspension Assembly

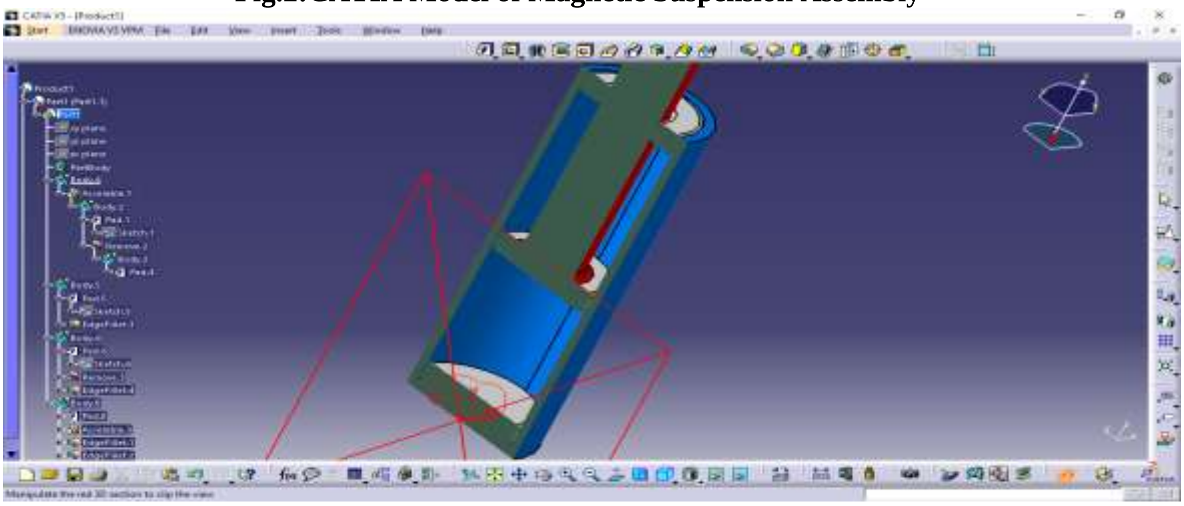

Fig.3:CATIA Model Of Magnetic Suspension Assembly (Cross-Section)

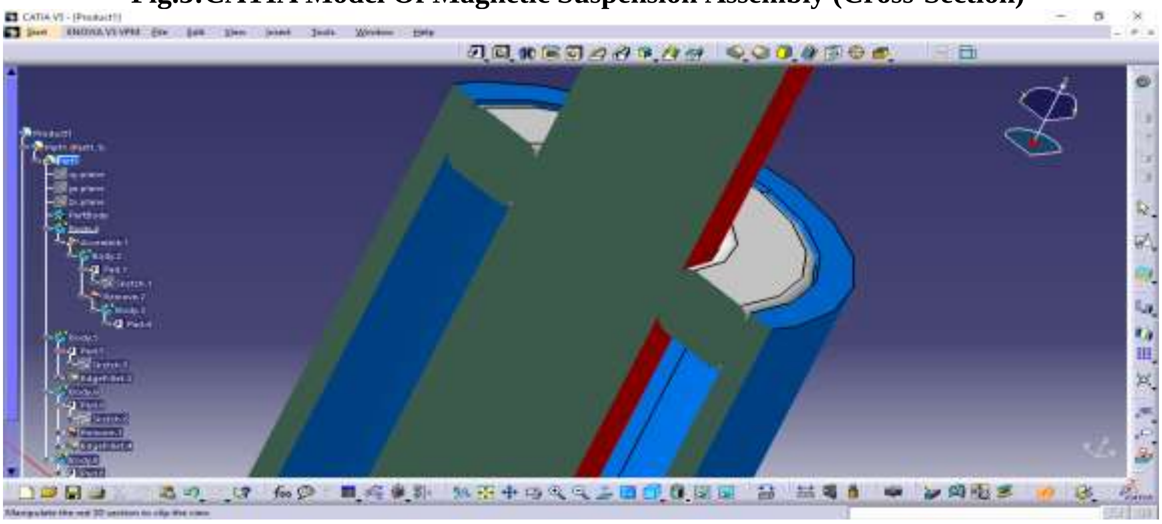

Fig.4:CATIA Model Of Top Fixed Magnet

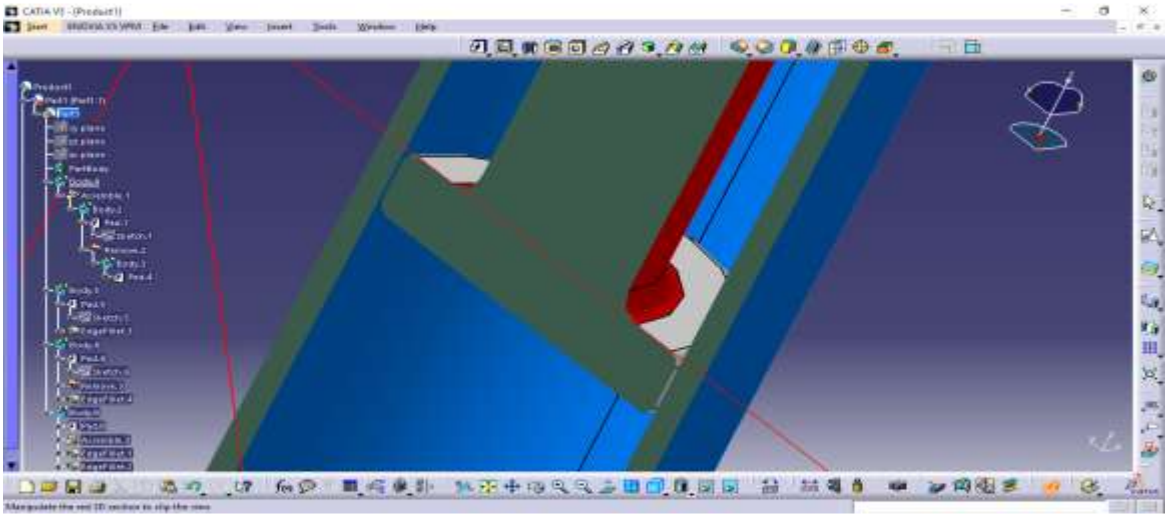

Fig.5:CATIA Model Of Magnet Fixed To The Strut

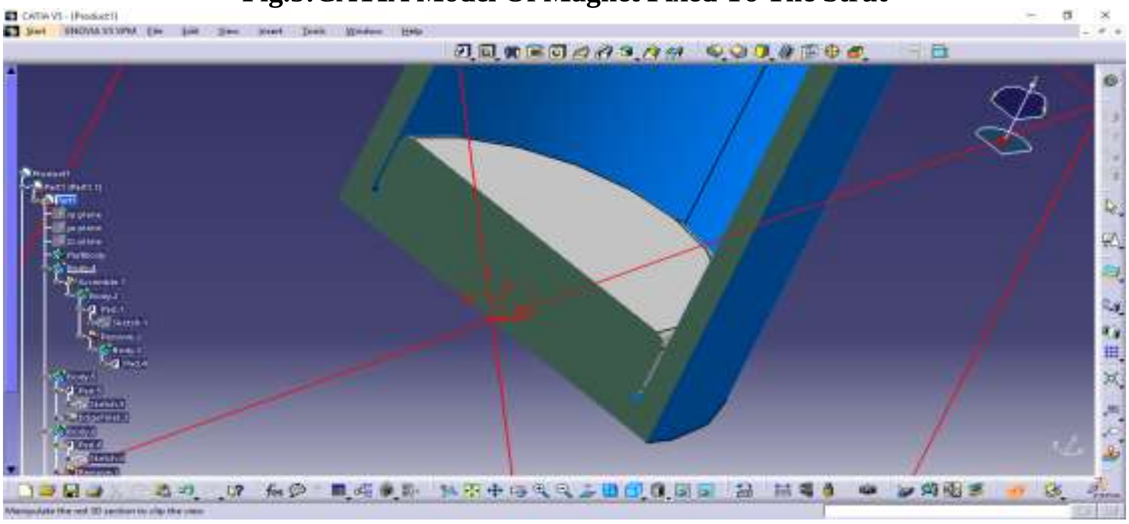

Fig. 6:CATIA Model Of Bottom Fixed Magnet

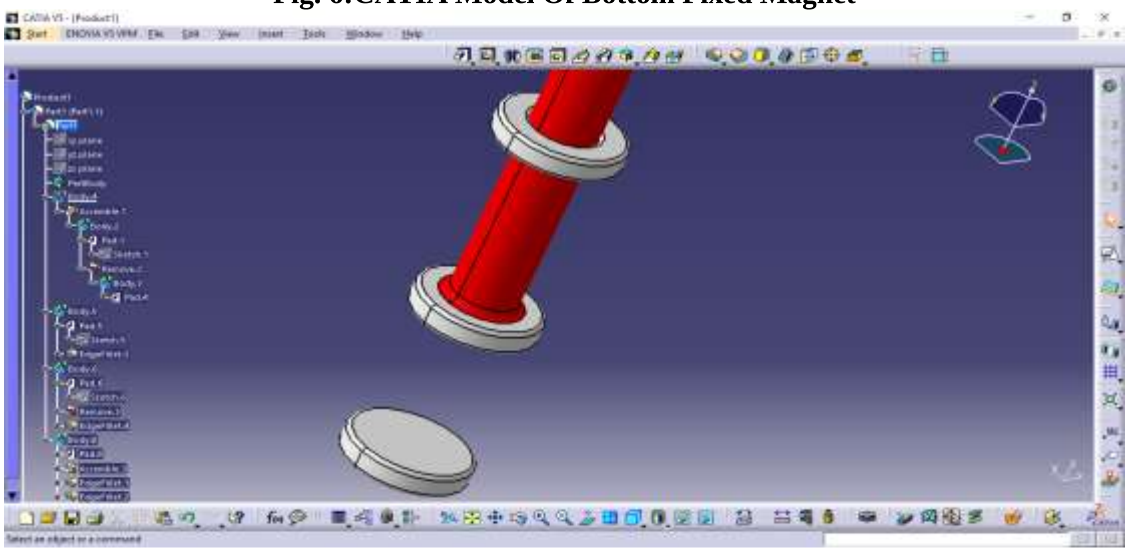

Fig.7:CATIA Model Of All Magnet Assembly

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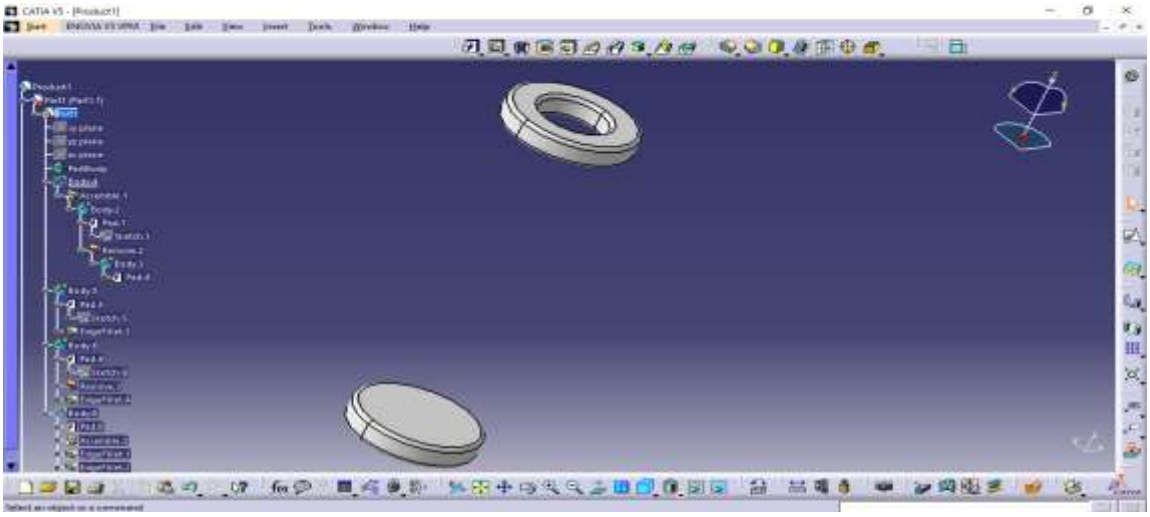

Fig.8:CATIA Model Of Fixed Magnet Assembly

VIII. COMPARISON OF MAGNETIC SHOCK ABSORBER WITH SPRING SHOCK ABSORBER

The idea for a magnetic shock absorber, makes use of the magnetic repulsion between dipoles to achieve shock absorption. Often when riding on her two wheeler we used to face some problems while moving on the bumpy road due to its unevenness.it observed that the like pole of two magnets of the same properties and strength repulse each other and they keep a constant distance between each other because of their magnetic fields this made her think that if the shock absorber are made of magnets with similar poles facing each other, it may give better performance and no maintenance would be required for the same. Table 2 shows the comparative study of magnetic with spring shock absorber.

Table 2: Comparative Study(Aniket Bharambe 2016)

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 the magnet is more.	The weight of the spring is less as compared to magnets.
4.	It has very low maintenance.	It has high maintenance.
5.	There is no heat generation.	There is heat generation because of friction.
6.	There is no requirement for a coil.	There is a requirement for coil.
7.	They can be used in vehicles carrying heavy or light load.	They can only be used in vehicles carrying light loads.
8.	The response of magnetic shock absorber is slow.	The response is comparatively fast.

IX. CONCLUSION

Due to the change in vehicle concepts form internal combustion (IC) to the electric car, the suspension system becomes ever more important due to changes in the 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 be used as an option to the conventional suspension system. This model of the suspension system has a higher working life than the coil spring system. The latter is exposed to 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.

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