Design and Fabrication of Magnetic Suspension

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Abstract- This paper gives outlines magnetic suspension where two or more magnets of the same polarity absorb all the bumps. The design and analysis for rear wheel bike magnetic suspension is discussed. This paper describes techniques for 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 placed at bottom of the inner portion of cylinder that reciprocates up and down due to repulsion. The two magnets fight against each other to achieve the aspect of suspension.

Index Terms -Magnetic Suspension; Repulsion; Bumps; Polarity.

1. INTRODUCTION

In today's world automobile 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 one to an advanced technology. E.g. the carburetor is now being replaced by microprocessor controlled fuel injection system.

In two wheelers suspension system used is coil spring but the limitation of that coil spring is that after some period of time it becomes not only harder but also reduces the cushioning effect. This limitation is overcome by magnetic suspension. The cushioning effect provided by magnetic suspension is existing for long-time.

2. 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 a 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 = 1000gauss = 1weber flowing through 1 square meter, and is a very large amount of magnetic flux.

3. CONCEPT

Unlike poles of a magnet attract each other and like poles repel each other. 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. In this suspension a set of magnets have been selected like poles, then it is placed into in a hollow cylinder. One magnet is fixed at the top of the inner portion 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.

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 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.

4. SELECTION OF MATERIAL

The proper selection of material for the different part of a suspension is the main objective in the fabrication of suspension. For a design engineer it is must that be familiar with the effect, which the manufacturing process and heat treatment have on the properties of materials. The choice of material for engineering purposes depends upon the following factors:

- Availability of the materials.
- Suitability of materials for the working condition in service.
- Cost of materials.
- Physical and chemical properties of material.
- Mechanical properties of material.
- Manufacturing conditions

The mechanical properties of the metals are those, which are associated with the ability of the material to resist mechanical forces and load. We shall now discuss these properties as follows:

- Strength: It is the ability of a material to resist, without rupture, external forces causing various types of stresses. Strength is expressed as tensile strength, compressive strength or shear strength.
- Stress: Without breaking or yielding. The internal resistance offered by a part to an externally applied force is called stress.
- Stiffness: it is also called as rigidity. It is the ability of material to resist deformation under the action of external loads. The modules of elasticity of the measure of stiffness.
- Ductility: Ductility is defined as the ability of material to deform to a greater extent before the sign of crack, when it is subjected to tensile force. A ductile material must be both strong and plastic. The ductility is usually measured by the terms, percentage elongation and percent reduction in area. The ductile materials commonly used in engineering practice are mild steel, copper, aluminum, nickel, zinc, tin and lead.
- Brittleness: It is the property of material opposite to ductile. It is the property of material which shows negligible plastic deformation before fracture takes place. Brittle materials when subjected to tensile loads snap off without giving any sensible elongation. Cast iron is a brittle material.
- Resilience: It is the property of a material to absorb energy and to resist rock and impact loads. It is the ability of material to absorb energy within elastic range. It is measured by amount of energy absorbed per unit volume within elastic limit. This property is essential for spring material. Resilience is measured by a quantity, called modulus of resilience.
- Creep: When a part is subjected to a constant stress at high temperature for long period of time, it will undergo a slow and permanent deformation called creep. This property is considered in designing internal combustion engines, boilers and turbines.
- Hardness: It is a very important property of the metals and has a wide verity of meanings. It embraces many different properties such as resistance to wear scratching, deformation and machinability etc. It is defined as the resistance of the material to penetration or permanent deformation. It also means the ability of the metal to cut another metal. The hardness is usually expressed in numbers, which are dependent on the method of making the test. The hardness of a metal may be determined by the following test.
- Brinell hardness test
- Rockwell hardness test
- Vickers hardness (also called diamond pyramid) test and
- Share scaleroscope.

The knowledge of materials and their properties is of great significance for a design engineer. The machine elements should be made of such a material which has properties suitable for the conditions of operations. In addition to this a design engineer must be familiar with the manufacturing processes and the heat treatments have on the properties of the materials. In designing the various part of the machine it is necessary to know how the material will function in service. For this certain characteristics or mechanical properties mostly used in mechanical engineering practice are commonly determined from standard tensile tests. In engineering practice, the machine parts are subjected to various forces, which may be due to either one or more of the following.

- Energy transmitted
- Weight of machine
- Frictional resistance
- Inertia of reciprocating parts
- Change of temperature
- Lack of balance of moving parts

The selection of the materials depends upon the various types of stresses that are set up during operation. The material selected should with stand it. Other criteria for selection of metal depend upon the type of load because a machine part resist load more easily than a live load and live load more easily than a shock load.

Selection of the material depends upon factor of safety, which in turn depends upon the following factors.

- Reliabilities of properties
- Reliability of applied load
- The certainty as to exact mode of failure
- The extent of simplifying assumptions
- The extent of localized
- The extent of initial stresses set up during manufacturing
- The extent loss of life if failure occurs
- The extent of loss of property if failure occurs

Material used: - Mild steel
Reasons:

- Mild steel is readily available in market
- It is economical to use
- It is available in standard sizes
- It has good mechanical properties i.e. it is easily machine able
- It has moderate factor of safety, because factor of safety results in unnecessary wastage of material and heavy selection. Low factor of safety results in unnecessary risk of failure
- It has high tensile strength

- Low co-efficient of thermal expansion

4.1 ***Magnetic Material Properties***

4.1.1Neodymium magnet:-A neodymium magnet or NIB magnet is also called a rare-earth magnet. Neodymium magnet is a powerful magnet made of a combination of neodymium, iron, and boron — Nd2Fe14B.

5. DESIGN OF MAGNETIC SUSPENSION SYSTEM

5.1 *Design of Main Spring*

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 *Sut* =0.5×1190=595 N/mm^2

Spring index $C = \frac{D_o}{d}$

= 40/5

C = 8

Then Wahl factor of spring

$$K = \frac{4C-1}{4C-1} + \frac{0.615}{C}$$

For C =8 K= 1.18
Now to find load holding by spring P

$$\text{Shear stress} = \frac{8KPD_o}{\pi d^3}$$

P = 618.47 N

Thus spring hold the load of 708.54 N remaining load is absorbed by magnet.
Deflection of spring (δ) can calculate by

$$\delta = \frac{8PN{D_o}^3}{Gd^4}$$

δ=56.04 mm

$$\text{Spring rate} = \frac{P}{\delta}$$

= 11 N /mm
Spring stiffness= K = 11 N/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

Solid length of spring Ls = N_T x d

= 11 x 5

= 55 mm

Free length of spring

L_f = solid length +deflection + axial gap
= 55 + 56 + 0.15(δ)
= 55 + 56 + 0.15(56)
L_f = 120 mm.

$$\text{Pitch of spring} = \frac{L_f}{N}$$

Pitch of spring =13.33mm

Fig. 5.1Main Spring

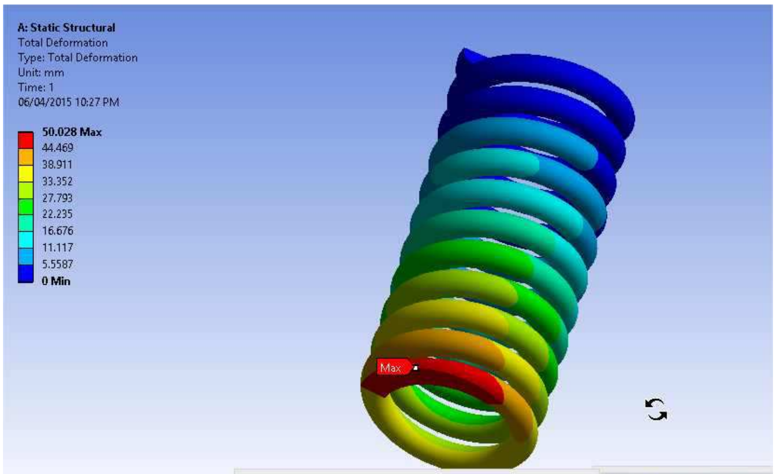

Fig. 5.2Anlysis of spring in Ansys

5.2 *Design of Magnet:-*

- Power of magnet pair = 10000 Gauss power
- Weight of vehicle body= 135 kg =1324 N
- Weight of person sitting on vehicle = 150 kg =1471 N
- Total load = Weight of vehicle body + Weight of person sitting on vehicle

Total load = 1324+ 1471 = 2795 N

Rear Suspension = 65% of total weight= 1816 Kg
Considering dynamic loads double (W) =3634 N

For single shock absorber weight = W/2= 1817 N

Taking factor of safety = 1.2

So design load = 2180 N

Magnetic power per unit area = 2 N/ mm^2

So area required for suspension of 350 kg load

2 = 2180/ A

A = 2180/2

A= 1090 mm^2

1090 = 3.14 / 4 x D^2

Diameter of magnet = 37.3 mm

Approximately diameter of magnet=37mm

Fig. 5.3Magnet

5.3 Design of Shaft

The shaft is subject to pure bending stress

Design force = 2180N

Bending length = 165 mm

Bending moment = F x L

Bending moment = 2180 x 165 = 359700 N –mm

M = 3.14/32 x F_b x d^3

359700 = 3.14/32 x 865 x d^3

D = 17.1825mm

D = 18 mm

Design of Hollow cylinder

M = F_b x l

M = 2180 x 200 = 436000

M = 3.14/32 x F_b x do^3 $(1 – k^4)$

436000 = 3.14 /32 x F_b x 87^3 $(1 – 0.89^4)$

F_b = 20 < 35 N/mm^2

As induced stress is less than allowable stress the design of hollow cylinder is safe.

Fig. 5.4Shaft

5.3 Setup Assembly

Fig. 5.5Assembly

6. CONCLUSION

6.1 Spring life increase

In this work spring inside the cylinder so that there is no any contact with dust particle, moisture of atmosphere, hence corrosion is reduced and spring life is increased. As per theoretical and analysis data here conclude that spring is safe.

6.2 Reduced cost

In conventional system hydraulic damper is used for damping purpose, in this system same magnetic poles are follow same function that means here the damper and oil cost is eliminated due to that overall cost of the system is reduced.

6.3 Comfort to rider

Here road shocks are absorbed by spring and magnet so that is gives comfort to rider

6.4 Easy to customize

6.5 Easy for maintenance

7. FUTURE SCOPE

7.1 Replacing the permanent magnet with electromagnet.
7.2 Analyze data of natural frequency using FFT analyzer.

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