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Fabrication of Electromagnetic Damper

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Abstract: This research study investigates the development of an electromagnetic suspension system for application in high-speed transportation. Using magnetic fields, the technology is intended to elevate and stabilize a vehicle. The construction process and materials utilized to create the suspension system are described in the publication. Testing and evaluating the system's performance, such as its capacity to retain stability and levitation under varying speeds and loads, are part of the research. The research also investigates the effects of changing electromagnetic field parameters on system performance. The study's findings indicate that electromagnetic suspension systems are a promising technology for high-speed transportation, with applications in maglev trains and other comparable vehicles.
Keywords: Electromagnetic suspension, Magnetic fields, Stability, Energy conservation

I. INTRODUCTION

Shock absorbers, linear dampers, and dashpots are linear motion devices that absorb shocks and give smooth deceleration. They can be mechanical, like elastomeric or coil spring dampers, or they can rely on a fluid (gas, air, or hydraulic) to absorb shock by permitting regulated passage from the outer to the inner chamber of a cylinder during piston actuation. The piston rod is normally restored to the unloaded position in traditional shock absorbers by a spring. Shock absorbers usually have a fluid or mechanical dampening system as well as a return mechanism to the unengaged position. They range in size from small consumer gadgets to huge industrial and civil engineering applications. They range in size from small consumer gadgets to huge industrial and civil engineering applications. Linear dampers are a broad phrase that refers to various dashpots and shock absorbers. They are often employed for devices that are intended to dampen reciprocating motion rather than absorb huge shock loads.
Dashpots are distinguished because, while they employ regulated fluid flow to dampen and decelerate motion, they do not always have an integrated return mechanism, such as a spring. Dashpots are small, precise devices that are commonly employed in applications that demand regulated, smooth action, such as mechanical and electrical equipment.

A. *Permanent Magnet System Shock Absorber*

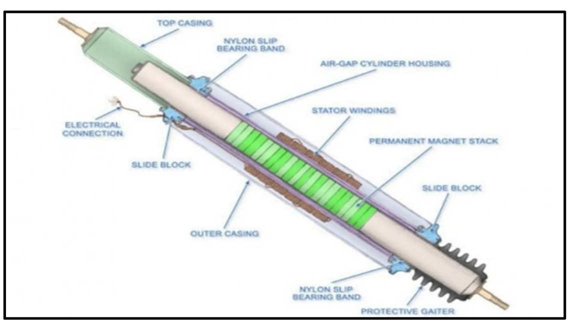

Fig No 1. Magnetic shock Absorber with Regeneration

The suspension apparatus uses a plurality of sets of permanent magnets to maintain a spaced relationship between a first movable member and a second fixed member. It provides dampening, cushioning, stabilizing, harmonic balancing, and/or reflexive re-centering forces. The apparatus includes sets of permanent magnets located within a case coupled to the movable member and an elongated support member coupled to the fixed member. The sets of permanent magnets are arranged in a bidirectional repulsion configuration and moved relative to the fixed permanent magnets to increase the magnetic forces of repulsion in response to the relative movement between the support member and the case. The control mechanism can be used in any equipment or machinery having a movable and non-movable member.

The regenerative electromagnetic shock absorber includes a linear electromagnetic generator comprising central magnet arrays and an inner coil array mounted on movable coil support. An outer magnet array assembly surrounds the inner coil array, and a voltage conditioning circuit is electrically connected to coil windings, providing an output voltage and output current to an electrical load. The apparatus provides a maximum average radial magnetic flux density in the inner coil windings through predetermined location, configuration, and orientation of magnetic poles, spacers, and coil windings.

II. LITERATURE REVIEW

In the 2012 paper by Andrzej Milecki and Mikołaj Hauke, the use of Magnetorheological (MR) fluid in industrial shock absorbers is discussed. The MR fluid can control the stopping process of moving objects, such as those on transportation lines. The proposed solution allows for the adjustment of the braking force, via electronic controller, to the kinetic energy of the moving object, providing an optimal braking process.

The paper overviews traditional passive shock absorbers and proposes a design concept for a semi-active shock absorber utilizing MR fluid. Passive shock absorbers that are currently in use do not guarantee optimal stopping as their braking force is not constant throughout the stroke of the absorber. Hence, there is a need for improvement, and semi-active devices have been proposed for damping vibrations and oscillations.

These devices, also known as "intelligent" devices, allow for the continuous change of parameters such as the movement opposite force, with minimal energy requirements.

Such devices utilize electrorheological (ER) or MR fluids, with MR fluids being more commonly used due to their strength and ability to be operated directly from low-voltage power supplies. The use of MR fluid in shock absorbers has potential applications in the stopping of moving elements on production lines. Theoretical analysis shows that the optimal braking process occurs when the braking force is constant throughout the stroke of the absorber. This paper proposes a solution utilizing MR fluid to achieve this optimal braking process.

A. Investigations Of Shock Absorber With Magnetorheological Fluid

In 2008, Babak Ebrahimi, Mir Behrad Khamesee, and M. Farid Golnaraghi conducted research on the design and modeling of a magnetic shock absorber based on the eddy current damping effect. Eddy currents are generated in a conductor in a time-varying magnetic field, either by the movement of the conductor in the static field or by changing the strength of the magnetic field, resulting in motional and transformer electromotive forces (EMFs).

The generated eddy currents create a repulsive force that behaves like a viscous damper proportional to the velocity of the conductor.

Graves et al derived a mathematical representation for eddy current dampers, based on the motional and transformer emf, and developed an analytical approach to compare the efficiency of dampers in terms of these two sources. The application of eddy currents for damping purposes has been studied for over two decades, including magnetic braking systems, vibration control of rotary machinery, structural vibration suppression, and vibration isolation enhancement in levitation systems.

The researchers utilized the newly developed analytical model to design high-performance dampers for a variety of applications. The magnetic shock absorber designed in this study was based on the eddy current damping effect and included a bypass valve with a cylindrical gap mounted on the interface plate. The electro-hydraulic servo drive was used to control the piston velocity, and a Linear Variable Differential Transducer (LVDT) and HBM 5 KN transducer were used to measure the displacement and braking force. The measured signals were transformed into digital form by an analog/digital converter and sent to a computer for recording and analysis. This study provides insights into the design and modeling of high-performance dampers utilizing the eddy current damping effect.

III. COMPONENTS AND DESCRIPTION

The components of Electromagnetic shock absorbers are mainly categorized into two;

A. Mechanical Components

- Cylinder piston
- Coil Spring
- Permanent Magnets

1) Cylinder Piston Arrangement

The cylinder is the primary working component of the space through which a piston travels. It consists of two heads, with the upper head serving as a housing for an electromagnetic coil and core that generate a repulsive force when energized. The upper head is bored to a larger diameter to accommodate the electromagnet, and a hole is drilled at the top to allow connection to the coil. Mild steel is commonly used as the material for the cylinder because it is easy to machine

Fig No. 2 Piston Cylinder Arrangement

2) Permanent Magnet (Ferrite)

A magnet is a material or object that generates a magnetic field, which is responsible for its most notable property, the ability to attract or repel other ferromagnetic materials like iron or other magnets. Permanent magnets are objects made from materials that are magnetized and create their own magnetic field. Materials that can be magnetized are called ferromagnetic, which include iron, nickel, cobalt, and some rare earth metals and minerals such as lodestone. While ferromagnetic materials are strongly attracted to a magnet, other substances also respond weakly to a magnetic field by various types of magnetism. Permanent magnets are made from "hard" ferromagnetic materials that are subjected to a special process in a powerful magnetic field during manufacture to align their microcrystalline structure. This alignment makes them very difficult to demagnetize. In contrast, "soft" ferromagnetic materials like annealed iron can be magnetized but tend not to stay magnetized.

Electromagnets are made from a coil of wire that produces a magnetic field when an electric current passes through it but stops when the current stops. An electromagnet is often wrapped around a core of ferromagnetic material like steel, which enhances the magnetic field produced by the coil. The strength of a magnet is measured by its magnetic moment or total magnetic flux it produces. The local strength of magnetism in a material is measured by its magnetization. Magnetism has many practical applications, including in electric motors, generators, MRI machines, and many other devices.

Fig No 3: Magnet Ferrite Ring

Material	:	Ferrite
Shape	:	Ring
Outer Diameter	:	72mm
Inner Diameter	:	36mm

Property	Description
Composition	Ceramic material made of iron oxide (Fe2O3) and either strontium carbonate (SrCO3) or barium carbonate (BaCO3)
Magnetic Orientation	Anisotropic - can be magnetized in only one direction
Magnetization	Moderate magnetization, with a maximum energy product (BHmax) typically in the range of 1-4 MGOe (Mega-Gauss-Oersted)
Coercivity	High coercivity, which means they are resistant to demagnetization
Curie Temperature	The temperature at which the magnet loses its magnetic properties - typically between 200-450°C (392-842°F)
Electrical Conductivity	Low electrical conductivity - they are electrically insulating
Corrosion Resistance	High resistance to corrosion and oxidation
Cost	Relatively low cost compared to other types of permanent magnets

Table no.1 Properties of Ferrite Magnet

3) Coil Spring

Coil spring, also known as a helical spring, is a mechanical device that is typically used to store energy due to resilience and subsequently release it, absorb shock, or maintain a force between contacting surfaces. They are made of an elastic material formed into the shape of a helix that returns to its natural length when unloaded.

Springs can be classified depending on how the load force is applied to them:

a) Tension/Extension spring - the spring is designed to operate with a tension load, so the spring stretches as the load is applied to it.
b) Compression spring - is designed to operate with a compression load, so the spring gets shorter as the load is applied to it.
c) Torsion spring - unlike the above types in which the load is an axial force, the load applied to a torsion spring is a torque or twisting force, and the end of the spring rotates through an angle as the load is applied.
d) Constant spring-supported load will remain the same throughout the deflection cycle.
e) Variable spring - resistance of the coil to load varies during compression.

The suspension coil springs combined with shock absorbers prevent undesired vertical movement of the vehicle and suppress jolts and vibrations. An optimum design, an improved production process, and a new type of primary material make it possible to reduce the suspension coil spring weight by up to 50%. One type of coil spring is a torsion spring: the material of the spring acts in torsion when the spring is compressed or extended. The quality of the spring is judged by the energy it can absorb. The spring which is capable of absorbing the greatest amount of energy for the given stress is the best one. Metal coil springs are made by winding a wire around a shaped former - a cylinder is used to form cylindrical coil springs. A spring is an elastic object used to store mechanical energy. Springs are usually made out of spring steel.

Small springs can be wound from pre-hardened stock, while larger ones are made from annealed steel and hardened after fabrication. Some non-ferrous metals are also used, bronze and titanium, for parts requiring corrosion resistance.

Fig No. 4 Coil Spring

Material	Spring steel
Wire Diameter	3 mm
Outer Diameter	40 mm
No. of Turns	9
Length	254 mm

B. Electrical Component

1) Copper Winding

Copper winding refers to the use of copper wire or foil to create coils in an electrical or electromechanical device. Copper is a popular choice for winding due to its excellent electrical conductivity, thermal conductivity, and durability. It is commonly used in applications such as electric motors, transformers, generators, and inductors, where its high conductivity allows for efficient energy transfer and its durability ensures long-term reliability. Copper winding can also be designed to meet specific electrical and mechanical requirements for optimal performance.

Fig No.5 Copper Winding

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Material	Copper
Gauge	18
Shape	Round
diameter	1mm

IV. RESULTS AND CALCULATIONS

A. Calculation Of Spring

Were k=spring stiffness
D=diameter of spring-40mm
d=diameter of spring wire-3mm
N=number of turns-9
G=shear modulus of elasticity
For carbon steel SAF 1050
From design data book T V111-9
G=79 Gpa

Maximum deflection of spring 3 inches=76.2 mm
K=Gd^4/8D³N=1388.6718
Maximum force spring stiffness × maximum Deflection =1388.6718 0.0762 =1058.16N =**1000 N**

Let acceleration due to gravity=10 m/s^2
Weight=force/acceleration
Therefore, maximum weight =1000/10=100 Kg
Minimum deflection for which voltage is produced X min =0.003m
F min=13123X0.003810 =49.9986 =**5ON**

Therefore, minimum weight to obtain deflection W min =50/10 = 5 kg
Spring Index (C) = D/d =13.33mm
Shear stress factor (Ks)=1+1/2C = 1.0375
Wahl's Correction Factor (Kw) = (4C-1/4C-4)+(0.615/C) = 1.10
Pitch free length /(n-1) =**17.5 mm**

B. Repulsive Force Between Magnets

Radius of electromagnet, R = 3cm
Permeability of free space,, =411x10^-7 N/A²
Height of magnet, H
At normal condition the permanent magnet rest at distance of 10cm from the core, and the minimum distance when it comes during shock is 3cm. So there is a maximum and a minimum force, between these repulsion forces varies. As the distance between magnets decreases the force will increase. But when it comes closer the magnet will attract. So in order to avoid such situation a rubber bush is placed over the electromagnet.

Magnetisation, M=Nm/V, m-unit vector in that direction
=(250/54)*m
= 4.62 A/m

Therefore Repulsive force,

The force between two identical cylindrical bar magnets placed end to end [3]

$$F = \left[\frac{B_0^2 A^2 \left(L^2 + R^2\right)}{\pi \mu_0 L^2}\right] \left[\frac{1}{x^2} + \frac{1}{(x+2L)^2} - \frac{2}{(x+L)^2}\right]$$

where

When x =xl

i.e., x =3cm, Repulsive force will be maximum

Fmax = 4.23×10^-6 N

When x = x2

i.c., x =10 cm, Repulsive force will be minimum

Fmin =3.748×10^-7 N

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