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Electro-magnetic Suspension System in Vehicles

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Abstract: Suspension systems are integral to vehicle performance, playing a critical role in enhancing ride comfort, stability, and handling. By absorbing shocks and vibrations, suspension systems ensure a smoother ride for occupants, improve traction, and maintain optimal tire contact with the road. Effective suspension systems also contribute to overall vehicle safety by optimizing braking performance and manoeuvrability. In this research paper, we explore the design and analysis of electromagnetic suspension systems, focusing on their application in automotive engineering. The suspension system plays a critical role in providing passenger comfort, isolating occupants from road noise, bumps, and vibrations, and maintaining chassis stiffness. As vehicles evolve, the demand for sophisticated suspension systems that balance ride comfort, stability, and safety becomes increasingly important.

Keywords: Neodymium Magnets, Suspension, Electro-Magnetism, Ampere's law, Spring

I. INTRODUCTION

Vehicle suspension is a crucial system designed to absorb shocks and vibrations from uneven road surfaces, ensuring a comfortable and stable ride. Traditional spring-based suspensions, while effective to some extent, face challenges in adapting dynamically to changing road conditions. This limitation can lead to issues such as a compromise in ride comfort and handling performance.

The project explores an alternative solution using magnetic suspension, which aims to overcome the drawbacks of traditional spring-based systems. Magnetic suspension systems utilize the principles of magnetic levitation to suspend the vehicle's body, eliminating the need for conventional springs. By precisely controlling magnetic fields, this approach offers the potential for real-time adjustments to varying road conditions. This adaptability could result in improved ride comfort, enhanced stability, and superior handling performance, addressing the shortcomings of traditional suspensions and paving the way for a more advanced and efficient suspension technology in vehicles.

II. LITERATURE REVIEW

The following literature review provides a comprehensive overview of the existing research and advancements in the field of neodymium magnets and their use in suspension systems.

[1] Berk Yasar Yavuz, Tuna Alikasifoglu , Yigit Berk Ucuncu, “Electromagnetic Suspention System” Bilkent University-Fall 2019-EEE 351 Best project.

In this term project, the aim is to build a system that demonstrates the fundamental concepts that are covered in the course EEE-351. For this purpose, a literature review is conducted, in order to come up with a suitable project proposal. In this process, we came across with the topic electromagnetic suspension, which fascinated us as a group.

[2] Hazril.M.Isa,Wan Nor Liza Mahadi, Dahisar Ramli,Mohd.AzmanZainul Abidin, “A review on Electromagnetic suspention systems for passenger vehicle” (InECCE 2011).

This paper discusses all the design literature review for electromagnetic suspension systems for passenger vehicles. Electromagnetic suspension is the alternative for existing conventional suspension system that uses passive suspension system.

[3] Jeff Shepard, "Electromagnetic Active Automotive Suspension System", (2016).

In this paper the automotive suspension has two goals: passenger comfort and vehicle control. Comfort is provided by isolating the vehicle's passengers from road disturbances like bumps or potholes. Control is achieved by keeping the car body from rolling and pitching excessively and maintaining good contact between the tire and the road.

[4] Bart L. J. Gysen, Johannes J. H. Paulides,Jeroen L. G. Janssen,and Elena A. Lomonova “Active Electromagnetic Suspension System for Improved Vehicle Dynamics” (April 2010).

This paper offers motivations for an electromagnetic active suspension system that provides both additional stability and maneuverability by performing active roll and pitch control during cornering and braking, as well as eliminating road irregularities, hence increasing both vehicle and passenger safety and drive comfort.

[5] G Rajan kumar1, K Anil2, "A Review on Electromagnetic Suspension System", (Sep-17).
Efforts has been taken to review the design, working of Electromagnetic suspension which has potential to replace the existing pneumatic, mechanical and hydraulic suspension systems. This electromagnetic suspension system was designed to anticipate and rise above bumps in the road, a little like riding on a magic carpet.
[6] Prof. Sagar S. Khatavkar, Mr. Dinesh Anchan, Mr. Prathamesh Deo, Mr. Samruddha Kale, Mr. Krushna Umate, "Electromagnetic Suspension System-A Review" (March 2016).
This paper is a review on design and modification of electromagnetic suspension, rear suspension, magnetic suspension, uses of shock absorber etc.
[7] Shende Vignesh1, Nimbalkar Hrishikesh3, Pawar Sanjay4, Thorat Vijay2, Raut P.S 5, "Magnetic Suspension System for Two-Wheeler", (October 2015 – March 2016).
This project is based on suspension system of a two-wheeler. This report gives information about magnetic suspension system. The aim of this project is to study and investigate the response of system, when it is subjected to road surface irregularities with the hope that it would help automobile industry.
[8] Kusumanchi Sai Avinash, Mohit Chauhan2, Sudeep Mall3, Karna Sai Ganesh Karthik4, Tanmoy Banik5, Sudhanshu Dogra 6, "A Review on suspension system design", (November 2020).
This paper presents various aspects of suspension system and the work done by various researchers in this area. A suspension system isolates the vehicle from wheel and road vibration and absorbs most of the shock. In this paper a review has been done of various suspension systems and their design configurations.

III. THEORY

Vehicles require suspension systems to absorb shocks and vibrations, with spring suspensions being the most common type. While traditional spring systems have been a mainstay, they face limitations in dynamically adapting to changing road conditions, potentially compromising ride comfort and handling, especially on uneven terrains. The challenges lie in the springs' inability to adjust in real-time and the drawbacks of dampers, such as high initial costs. Recognizing these drawbacks, the automotive industry explores alternatives like electro-magnetic suspension, which utilizes magnetic levitation principles to eliminate traditional springs. Through controlled magnetic fields, these systems offer adjustments to road conditions, potentially enhancing ride comfort, stability, and handling. As the industry evolves, factors like efficiency, power consumption, cost, and safety shape the future of vehicle suspension technologies.

Fig. 1: Conventional spring-damper suspension system [3]

A neodymium (NdFeB) magnet (Fig. 4) is a powerful rare-earth permanent magnet alloy of neodymium, iron and boron, developed in 1982, representing the strongest commercially available permanent magnets. Crucial for magnetic repulsion and levitation, neodymium magnets facilitate robust repulsion via substantial forces from intense fields when like poles interact, applied in bearings and couplings. They overcome gravity for levitation in displays and industrial systems by suspending objects, underscoring their significance in harnessing repulsion and levitation phenomena across scientific and technological innovations.

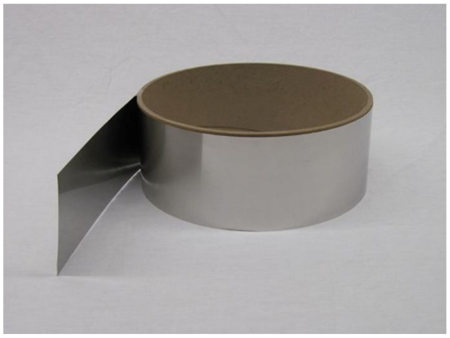
Fig 2: Neodymium magnets in a button shape [4]

Calculations:
The magnetic moment of a magnet can be calculated using the following formula:

$$m = V\,x\,H\,x\,\chi$$

where:
m = magnetic moment (in Am2)
V = volume of the magnet (in m3)
H = magnetic field strength (in A/m)
χ = magnetic susceptibility (unitless)

To calculate the magnetic moment of a magnet with a 10 mm diameter and 2 mm thickness, we need to first calculate its volume:

$$V = \pi\,x\,r2\,x\,t$$

where:
r = radius of the magnet = 5 mm
t = thickness of the magnet = 2 mm

V = π x (5 mm)2 x 2 mm
V =157 mm3 or 1.57 x 10-7 m3
Assuming that the magnet is made of a material with a magnetic susceptibility of 1 (such as neodymium), and is in a magnetic field of 1 tesla (which corresponds to a magnetic field strength of 79577 A/m in vacuum), the magnetic moment of the magnet can be calculated as:

m = V x H x χ
m = 1.57 x 10-7 m3 x 79577 A/m x 1
m = 12.5 Am2
Therefore, the magnetic moment of a magnet with 10 mm diameter and 2 mm thickness made of a material with a magnetic susceptibility of 1 and in a magnetic field of 1 tesla is approximately 12.5 Am2.
The stiffness of suspension can be adjusted with adjusting initial distance between two magnets.

IV. METHODOLOGY

A. Working:
A model was made to demonstrate the use of magnetic suspension in a vehicle. The magnets used were neodymium magnets of 10mm in diameter and 2 mm in width. A magnet is loaded into the cylindrical tube while another is attached to the plunger in such a way that the faces of the magnets are of same polarities; they will always repel each other.

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As the magnets' ability to move is constrained both by the walls of the tube and the weight of the plunger acting from above, a gap is created between the two of them. This levitation gap will form the heart of the suspension system, acting as a cushion. The other end of the plunger is attached to the main chassis. The tube is wrapped by coil .

When the vehicle moves over bumps in the road, the wheel assembly will deflect upwards. The cushion generated by the repulsive forces between the magnets will prevent the chassis from being affected by the displacement of the wheel assembly, thus ensuring a smooth ride.

B. Components:

1) Neodymium Magnets
2) Syringes (as suspension pipe)
3) Solenoids (Copper Wire)
4) Motor Driver with H-Bridge (LN298N)
5) Power Source
6) Microcontroller (Arduino)
7) Bluetooth Module (HC-05)
8) Chassis and Wheels
9) Gear motor

V. RESULTS

Assumptions

Parameters	Notations	Values	Unit
Outer diameter	Do	25	mm
Length of spring	L	82	mm
Number of turns	n	11	
Wire diameter of spring	d	2.5	mm
Wahl's correction factor (	K	1.18	

Material Selection

Selected Material	Steel
Shear stress	600 N/mm^2

Calculations

Parameters	Notations	Values	Unit
Inner diameter	Di	20	mm
Spring index	c	10	
Load carried by spring	P	708	N

Fig 3: Calculations of spring from V. B. Bhandari.

Assumptions

Parameters	Notations	Values	Unit
Weight of vehicle	W	15	kg
		147	N
Weight of driver	Wd	60	kg
		588	N

Calculations

Parameters	Notations	Values	Unit
Total load	Tw	735	N
Load on rear suspensions	Pr	477.75	N
Total static load	Ps	955.5	N
Weight on single shock absorber	W1	477.75	N
Factor safety		1.2	
Design load	P	573.3	N
Area of spring	A	286.65	mm^2
Diameter of magnet	ds	50	mm

Fig 4: Calculations of magnet for a vehicle of 15 kg..

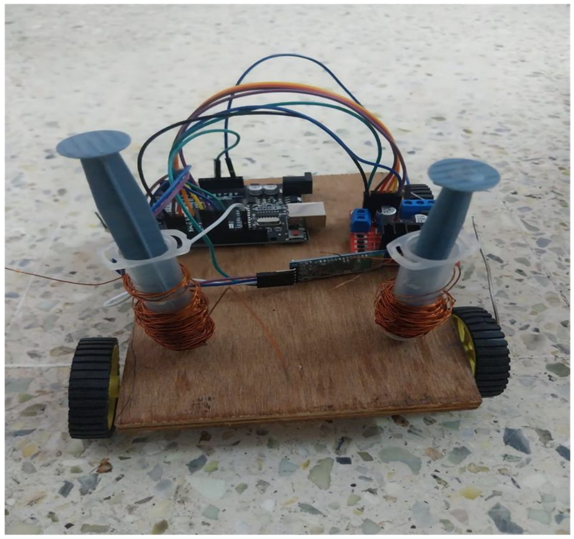

Fig.5 Suspension System model

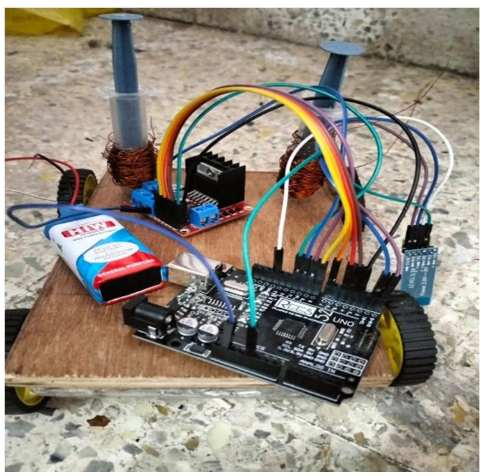

Fig.6 Suspension System Model

VI. ADVANTAGES

This system has to come up with strategies that can overcome the disadvantages of traditional suspension systems like weight, power consumption, heat dissipation, efficiency etc. When the system has been designed and prone to some tests, the results of the system are summarized, and the advantages of the system are listed.

1) Efficiency increases
2) Improved dynamic behaviour
3) Maintains stability
4) Accurate force control
5) Dual operation of the actuator.

VII. FUTURE SCOPE

Electro-magnetic suspension in Vehicles appears to have a bright future. In the future, each wheel could have an independent system, thus ensuring localised adjustment to bumps in the road and enabling the riders to have an even smoother ride. Improvements could include increased stability, better ride comfort, and increased energy efficiency. The goal of research and development could be to improve technology so that it can be widely used in different kinds of vehicles, making transportation easier and more effective. Furthermore, applications for improved control and safety in autonomous vehicles may exist.

VIII. CONCLUSION

The development of all types of electromagnetic suspension And its performance results also presented in this paper. For a suspension to work properly the adjustment of braking force to kinetic energy of a moving object is important. As the technology emerging continuously and precision manufacturing technologies are widely available and there are more modern methods to measure the reliability, efficiency and performance of suspension system, the electromagnetic suspension system has the capabilities to replace the existing suspension system, or it may club with existing systems. The adoption this system to automobile will benefit the passenger by providing more comfort, control and safety.

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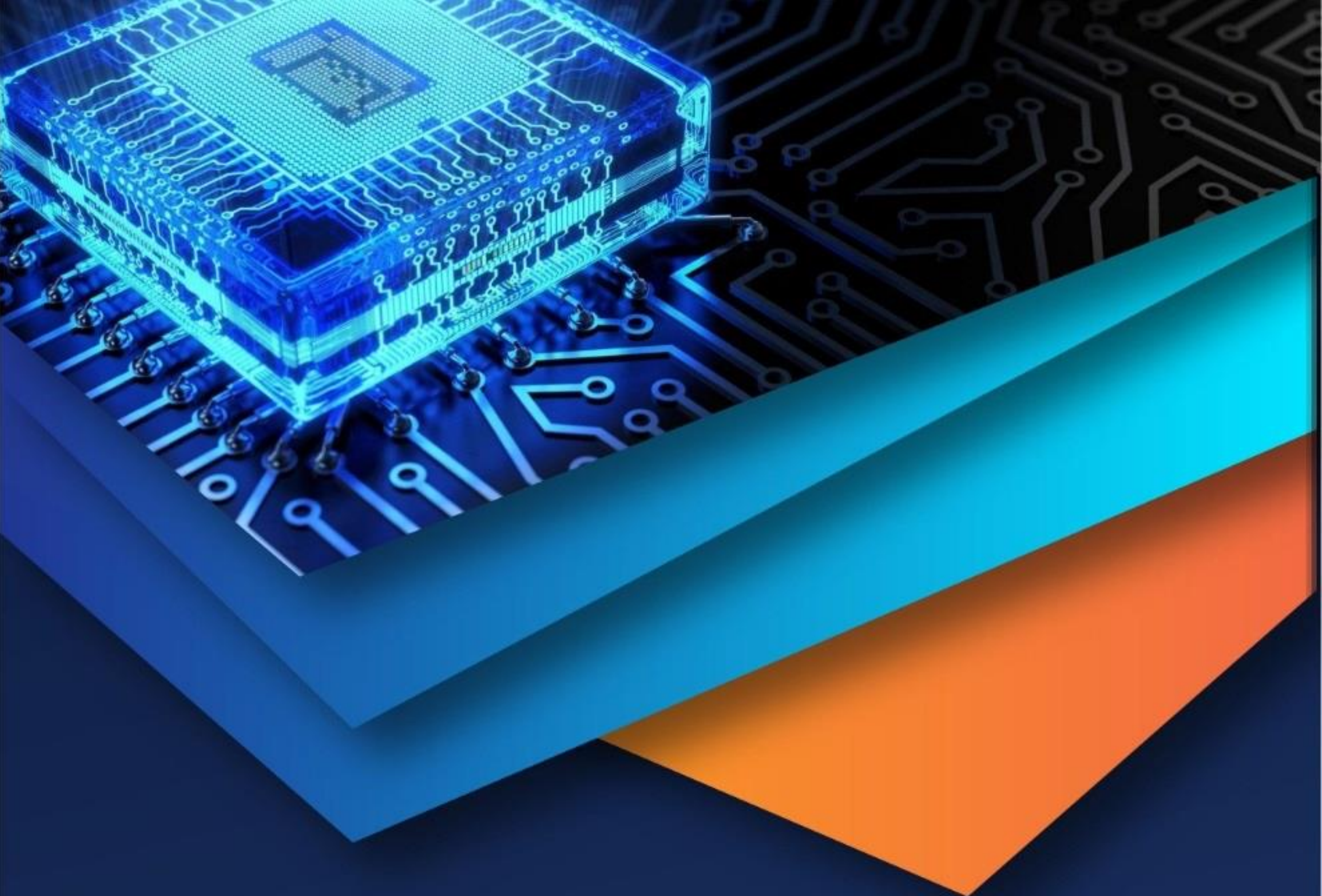

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