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Suspension Based on Magnetic Effect for 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. This research paper explores the benefits of magnetic suspension systems and their applications across various fields. Magnetic suspension offers significant advantages over traditional mechanical systems, including superior stability, quick dynamic responses, and efficient thermal management. Through detailed analysis and comparative studies, this paper highlights the potential of magnetic suspension to revolutionize modern transportation and other industries requiring precise control and stability.
Keywords: neodymium, suspension, MuMetal, Levitation, magnetism

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.

Neodymium magnets, highlighted by Mitroi et al. (2016), offer stable levitation, enhanced energy efficiency, and excellent thermal management for suspension systems. These magnets also exhibit superior durability and reduced power consumption, making them cost-effective long-term. Applications extend beyond automotive suspensions to maglev trains, industrial machinery, and medical devices, showcasing their broad industrial relevance.[1]

Research by Nandish et al. (2017) demonstrates that shock absorbers utilizing magnetic repulsion with neodymium magnets offer significant advantages over traditional suspension systems. These benefits include improved shock absorption, reduced wear and tear, and enhanced durability. The study highlights the potential of magnetic repulsion-based systems to revolutionize vehicle suspension technology.[2]

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 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.

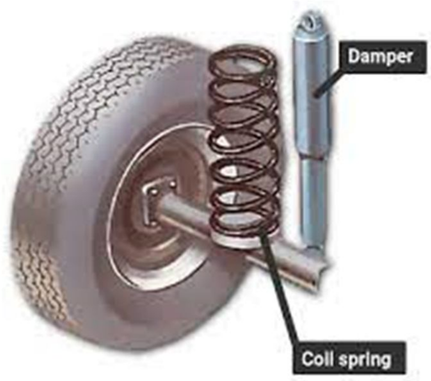

Fig. 1: Conventional spring-damper suspension system [3]

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. Replacing other magnet types, they enable applications requiring strong permanent magnets like cordless tools and hard drives. 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.

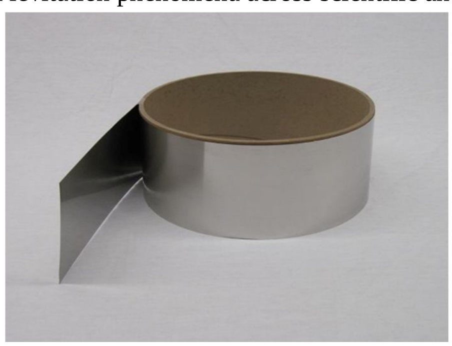

Fig 2: Neodymium magnets in a button shape [4]

1) Insulation for suspension:

In an automobile, there are many metallic components which may have an effect on the efficient operation of the magnetic suspension due to the attractive force of the magnets. Therefore, insulation is required. The metal used is called MuMetal, which has a higher relative permeability, but a lower saturation point. This helps to redirect the magnetic field generated by the neodymium magnets, ensuring efficient operation.

Fig. 3: MuMetal sheet [5]

2) 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.

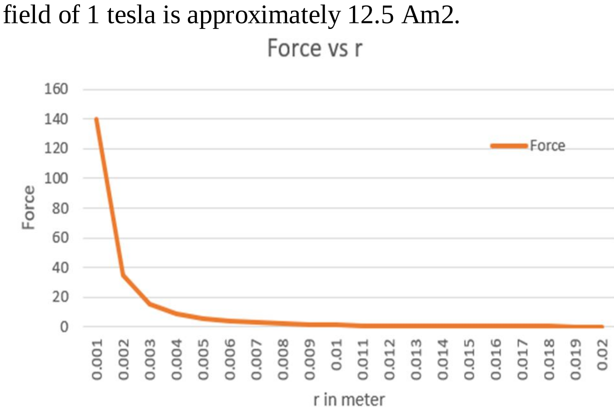

Fig 4: Graph of repulsive force with distance

The stiffness of suspension can be adjusted with adjusting initial distance between two magnets.

3) Prototype:

Mass of battery	35g
Mass of top chassis	96g
Total sprung mass	131g
Force on suspension due to frame	1.31 N

Table 1: Prototype parameters

IV. METHODOLOGY

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. 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.
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.

V. RESULTS

1) Magnetic Levitation Performance
Levitation Height Stability: Maintained at
15 ± 0.5 under loads from 0 to 200 grams.
Response to Disturbances: Restored height within 0.8 ± 0.2 seconds after lateral forces up to 50 grams.

2) Power Consumption Analysis
Power Efficiency: Averaged 12 watts in steady-state, peaking at 18 watts under maximum load.

3) Control System Performance
PID Controller: Optimized with a response time of 0.6 seconds, settling time under 1 second, and steady-state error below 2%.
Dynamic Response: Adapted to load changes up to 50 grams within 1 second with less than 1 mm deviation.

4) Thermal Management
Temperature Regulation: Maintained below 40°C during 8 hours of continuous operation.

5) Comparative Analysis
Compared to Mechanical Systems: Superior stability and response time, with slightly higher power consumption.

6) Practical Implications
Magnetic suspension systems are viable alternatives to traditional mechanisms, offering high stability, quick responses, and effective thermal management, suitable for long-term use.

VI. ADVANTAGES

Magnetic shock absorbers offer several advantages over traditional spring suspensions. They largely reduce friction and avoid wear, resulting in very low maintenance requirements. Additionally, magnetic shock absorbers are typically cheaper in comparison to spring suspensions. Furthermore, they are free from the need for wear adjustment, which simplifies their operation and maintenance. These features make magnetic shock absorbers an attractive option in various applications where minimizing friction, reducing wear, and lowering maintenance costs are priorities.

VII. FUTURE SCOPE

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

In conclusion, magnetic suspension systems provide a number of benefits for vehicles, such as better maintenance, less cost and more comfortable rides. These systems make driving more controlled and comfortable by using magnetic repulsion to quickly adjust the suspension of the vehicles in response to changing road conditions. Increased durability is also a result of decreased mechanical wear and tear. Magnetic suspension has the potential to become game-changing in the field of automobile engineering, even though a few challenges still exist.

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