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Regenerative Suspension System for Vehicle-Based Electrical Power

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Abstract: ***Power Generating Suspension is an innovative vehicle suspension technology that converts mechanical energy produced due to road irregularities into useful electrical energy. In conventional suspension systems, vibrations and shocks caused by uneven road surfaces are dissipated as heat, resulting in energy loss. The power generating suspension system utilizes mechanisms such as electromagnetic, hydraulic, or piezoelectric energy harvesting to transform this wasted mechanical energy into electrical power. The generated energy can be stored in batteries or super capacitors and used to power on board electronic devices, sensors, lighting systems, or to support auxiliary loads in electric and hybrid vehicles. This system not only improves overall energy efficiency but also contributes to reduced fuel consumption and lower environmental impact. Despite challenges such as increased system complexity and initial cost, power generating suspension systems offers promising solution for sustainable and energy-efficient transportation in modern vehicles.***

I. INTRODUCTION

The rapid growth of the automotive industry has led to a continuous increase in energy consumption and environmental pollution. Conventional vehicles, as well as modern electric and hybrid vehicles, require efficient energy management systems to improve performance and reduce dependence on external energy sources. One of the major sources of energy loss in vehicles is the suspension system, where mechanical energy generated due to road irregularities is dissipated as heat through dampers. This loss of energy, although continuous during vehicle motion, remains largely unutilized.

The Power Generating Suspension System addresses this limitation by integrating energy harvesting mechanisms into the vehicle suspension. Instead of dissipating vibration energy, the system captures the vertical motion of the suspension and converts it into electrical energy. Various technologies such as electromagnetic generators, hydraulic energy recovery units, and piezoelectric materials are employed to achieve this conversion. The harvested energy can be stored and later used to power auxiliary systems such as lighting, sensors, infotainment units, and control modules, thereby reducing the load on the main power source In addition to energy recovery, power generating suspension systems can also contribute to improved ride comfort and vehicle stability. Advanced designs allow adaptive damping control, where the suspension characteristics change according to road conditions while simultaneously generating power. This dual functionality makes the system highly attractive for next generation smart vehicles

Furthermore, with the global shift toward sustainable transportation and stricter emission regulations, energy harvesting technologies have become increasingly important. Power generating suspension systems offer a promising solution by improving fuel efficiency in internal combustion engine vehicles and extending driving range in electric vehicles. Although challenges such as increased system complexity, cost, and durability still exist, ongoing research and technological advancements are steadily overcoming these limitations. Hence, power generating suspension systems represent a
significant step toward energy-efficient, ecofriendly, and intelligent vehicle design.

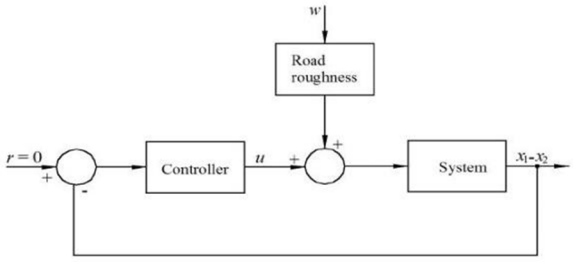


Fig. 1.1: Block Diagram of Power Generating Suspension System

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II. THEMATIC STUDY

A. Fundamental Concept of Power Generating Suspension

Power generating suspension is based on harvesting mechanical vibration energy generated due to road irregularities during vehicle motion. In a conventional suspension system, this vibration energy is dissipated as heat through dampers. In a regenerative suspension system, the same vibration energy is converted into electrical energy using an energy conversion mechanism without compromising ride comfort. In conventional vehicle suspension systems, the kinetic energy generated due to road-induced vibrations is dissipated as heat through shock absorbers. This results in significant energy loss, especially during continuous driving on uneven roads. Power generating suspension systems are designed to recover this wasted mechanical energy and convert it into electrical energy. The fundamental idea behind power generating suspension is to integrate an energy harvesting mechanism within the suspension assembly such that the relative motion between the vehicle body and wheel assembly drives an electrical generator. This approach enhances vehicle energy efficiency without altering the primary function of the suspension, which is ride comfort and stability

B. Energy Conversion Mechanism

The operation of a power generating suspension system can be divided into three main stages: Mechanical Energy Generation
When a vehicle moves over road irregularities such as bumps or potholes, vertical oscillations are induced in the suspension system. Mechanical-to-Electrical Energy Conversion The relative displacement and velocity of suspension components activate an energy conversion unit such as an electromagnetic generator, hydraulic motor, or piezoelectric element.
Electrical Energy Conditioning and Storage
The generated electrical output is typically AC and irregular. Power electronic circuits convert it into stable DC power and store it in batteries or super capacitors.

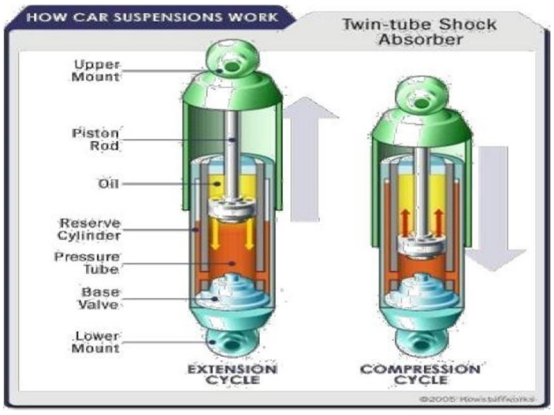


Fig 2.1: Energy conversion mechanism in power generating suspension system

C. Block Diagram and System Description of Power Generating Suspension

The block diagram of a power generating suspension system explains the overall functional architecture and energy flow from road excitation to electrical load. This system integrates mechanical suspension components with energy harvesting and power electronics to recover vibration energy effectively.

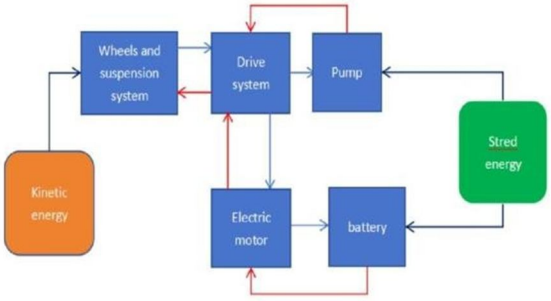


Fig. 2.2: Block diagram of power generating suspension system

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Road irregularities such as bumps and uneven surface act as external excitation forces that induce vertical vibrations in the suspension system.

Suspension System

The suspension system, consisting of springs and dampers, allows controlled relative motion between the wheel assembly and the vehicle body while maintaining ride comfort.

Energy Conversion Unit

The relative suspension motion drives the energy conversion unit. This unit may be electromagnetic, hydraulic, or piezoelectric, depending on system design, and converts mechanical vibration energy into electrical energy.

Electrical Power Generation

The energy conversion unit produces electrical output, generally in alternating current (AC) form, whose magnitude depends on suspension velocity and damping force.

Power Conditioning Circuit

The generated AC power is processed through rectifiers and DC–DC converters to obtain stable and usable DC output.

Applications of Power Generating Suspension

Power generating suspension systems are applicable in various modern transportation and energy-efficient systems due to their ability to harvest vibration energy and supply auxiliary power.

Electric Vehicles (EVs)

Power generating suspension systems can recover vibration energy and supply power to auxiliary loads, thereby extending battery range and improving overall vehicle efficiency.

Hybrid Vehicles

In hybrid vehicles, regenerative suspension contributes to energy recovery and reduces dependency on the internal combustion engine for auxiliary power.

Smart and Autonomous Vehicles

These systems can provide a reliable power source for sensors, control units, and monitoring devices used in autonomous driving systems.

III. MILITARY VEHICLES

Power generating suspension systems enable self powered on board electronics and communication systems, which are critical in remote and harsh environments.

A. Off-Road and Heavy-Duty Vehicles

Vehicles operating on rough terrains experience higher suspension vibrations, making them suitable for effective energy harvesting.

B. Vehicle Health Monitoring Systems

Harvested energy can be used to power sensors for real-time monitoring of suspension performance and vehicle condition. Energy Storage Unit

Conditioned electrical energy is stored in batteries or super capacitors for continuous and reliable power supply.

boards, interactive informational kiosks, or art installations in high traffic areas, making the power source directly proportional to audience engagement.

IV. CONCLUSION

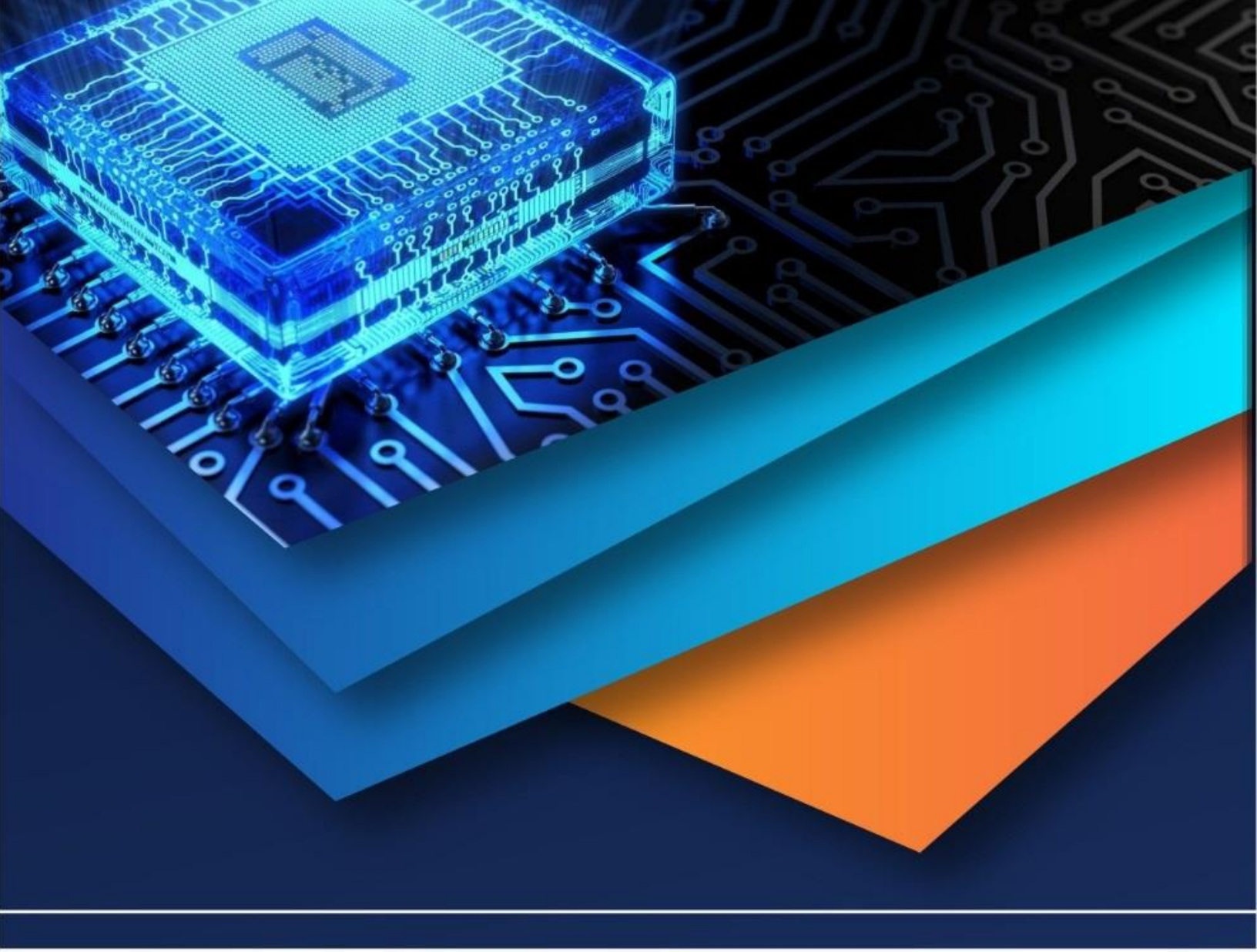
Power generating suspension systems offer a promising solution for recovering wasted mechanical energy generated by vehicle suspension vibrations. By integrating energy harvesting mechanisms such as electromagnetic, hydraulic, or piezoelectric systems into the suspension assembly, these systems convert vibration energy into useful electrical power without significantly affecting ride comfort or vehicle stability. Although challenges related to system complexity, cost, and durability still exist, continuous advancements in materials, control strategies, and power electronics are expected to enhance their performance and reliability. The adoption of power generating suspension systems can significantly contribute to energy-efficient, sustainable, and smart transportation technologies in the future.

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