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CREATING ELECTRICITY FROM AN AUTOMOBILE SPEED BUMP: A SUSTAINABLE ENERGY SOLUTION

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Abstract

Automobiles and other vehicles have become very essential in modern-day life. As the number of vehicles is increasing day by day, the speed at which they move is also increasing, necessitating the construction of speed bumps/dumps. Here, an attempt is made to harvest the kinetic energy of these moving vehicles as they cross the speed bumps, using a piezoelectric transducer, and then use it to illuminate the streetlight near the speed bump. The construction of these electricity-producing, energy-harvesting systems can be efficiently integrated with the speed dumps themselves such that they will not cause any obstruction or discomfort to vehicles and pedestrians. It is envisaged that these kinds of systems will pave the way for the installation of many sustainable energy solutions, especially in poor and remote locations where the laying of the grid for such small power requirements is not economical. This paper aims to analyze the feasibility and potential benefits of implementing electricity generation from speed bumps as a sustainable energy solution. The study will examine the technological and economic aspects of this innovative approach. It aims to analyze the feasibility and potential impact of implementing this technology in urban environments.

Keywords: *Speed Bump; Electric Generator; Mobility System; Recharging; Amortizing; Energy Efficiency; Information Systems.*

1. INTRODUCTION

Fossil fuels dominate current infrastructure, but renewable resources challenge their position in various electronic research disciplines. They support a reconstructive strategy with technological initiatives. Electronic communications integrated into infrastructure can contribute to intelligent operations and improvements in durability, compactness, and computational performance. Renewable resources encompass efficient operation, power management, wireless sensor networks, RFID, kinetic energy collection, and environmental tracking. (Ebhota and Jen2020)

Sustainable infrastructure balances human influence on the environment, economic growth, and conservation. Excessive exploitation disrupts nature and can hinder human activities. Conservation design choices and renewable resources are crucial for achieving sustainable growth. Implementing renewable energy sources and efficient systems contribute to a sustainable and cost-effective infrastructure. (Chen et.al.2022) (524 symbols)

1.1. Background and Significance

By use of a speed bump, the vehicle speed is reduced such as pollution in the atmosphere is decreased. At the same time, wastage energy in terms of vibration energy is released whenever a vehicle crosses a speed bump. This energy can be used to illuminate the street lights when it is connected to the street light via a suspension system. This paper presents the feasibility study of the electricity generation using a speed bump. The use of the speed bump in generating a renewable energy is a novel download for the Sustainable energy solution during the heavy traffic. (Patel et.al.2023)

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Vol: 61 | Issue: 09 | 2024

Transportation is revolutionized in every part of the world as automobiles are the most demanding sources of transportation. The most appealing feature of an automobile is that it is travel in a short time. Traffic congestion is the main problem facing by the automobile, which cannot be eliminated since the number of automobiles is increasing every day. This congestion affects the automobile's performance and the life of the vehicles. In order to overcome these problems, the world has been introduced to a new concept of traffic breaker called a Speed Bump, which obstructs the speed of vehicles and thus reduces the speed and in turn creates a reduction in speed near congested areas. (Karimi et. al.2021)

1.2. Purpose and Scope

Some researchers concluded that one of the benefits of the piezoelectric speed bump would be that over 10 years, the kilowatt cost/year averages 85 cents. The speed of the automobile or truck will determine the amount of piezoelectric electricity. Different models will require a different amount of electricity. The voltage can change from 5 V - 30 kV. The following paragraph will describe a device currently on the market. Today, the VeriShow 300 product line is used by fire departments, police departments for radar speed signs, industrial security, low-speed mobile plow trucks, the USA Department of Transportation, and the USA Road Commissions. At 45 mph, the product's piezoelectric generator will produce 20 watts. The VeriShow radar speed-monitoring device lights up when the automobile or truck speed exceeds 45 mph. If the speed is below 45 mph, the sign is off. The technological potential for piezoelectric simple devices is great. It can convert most mechanical energy into electric power. With simple modifications, the car speed bump could be modified as a renewable energy solution, contributing to the demand for brighter, cleaner, and healthier multifunctional outdoor lighting.

1.3. Paper structure

This paper has five sections: an introduction, Mechanism of Energy Generation, Design Considerations, Case Studies, and a conclusion. The introduction provides an overview of the research topic. Mechanism of Energy Generation explains the processes and mechanisms involved. Design Considerations discusses factors to consider in energy generation systems. Case Studies provide real-world examples. The conclusion summarizes key findings and suggests further research. This approach allows readers to engage, understand, consider, explore, and draw conclusions from the research.

2. MECHANISM OF ENERGY GENERATION

When the vehicle passes over the bump with a certain speed, work against the gravitational force is done by the vehicle, and this energy is transmitted to the bump and hence stored in the bump. Due to this, at any instant, the bump tends to move back to its original position. Thus, an external force is necessary to maintain the bump at the elevated position. This force is created on the spring, causing it to push the second magnet down. Then the motion of the second magnet causes a force of a similar nature on the permanent magnet coil of the generator. Thus, two similar motions at a small distance cause the generator to generate electricity. Hence, one can optimize the generator and place the speed bumps in such a way that they occupy minimal space. They might look a little bulky, but they will help to generate electricity in a minimal space. (Wu and Yan2024)(Njoku et.al.2023)

To generate power, some form of energy flow is necessary. The bump has stored potential energy due to the gravitational force acting on it. Once the vehicle passes over it, the stored gravitational energy is lost. In other words, the bump has to be moved against the gravitational force, so a force is necessary to move the bump. As the vehicle moves over the bump, it pushes it up by a certain height, which means that the bump has to be moved up against the gravitational force acting on it. Thus, an external force has to be applied to displace the bump upwards. This force has to be applied to the

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Vol: 61 | Issue: 09 | 2024

bump by the vehicle, and thus the bump starts to move up against the gravitational force with the help of the vehicle's speed. Due to this, there is an increase in the potential energy of the bump as it moves up and higher above the level of the road, and this energy will be stored as potential energy. The vehicle possesses mechanical energy, which is potential energy as well as kinetic energy, and there is gravitational force acting on the vehicle due to the Earth. (HASAN & AKASH, 2024)(Chiu et. al.2024)

2.1. Principle of Operation

To charge portable electronic devices with piezoelectric energy, a harvester called a multimodal energy harvester exists. This harvester taps into body motion to provide variable power output for different devices. By exciting the harvester at resonance, energy is harvested with high efficiency over a range of frequencies. (Yu et al. 2023) figure 1 shows piezoelectric system components

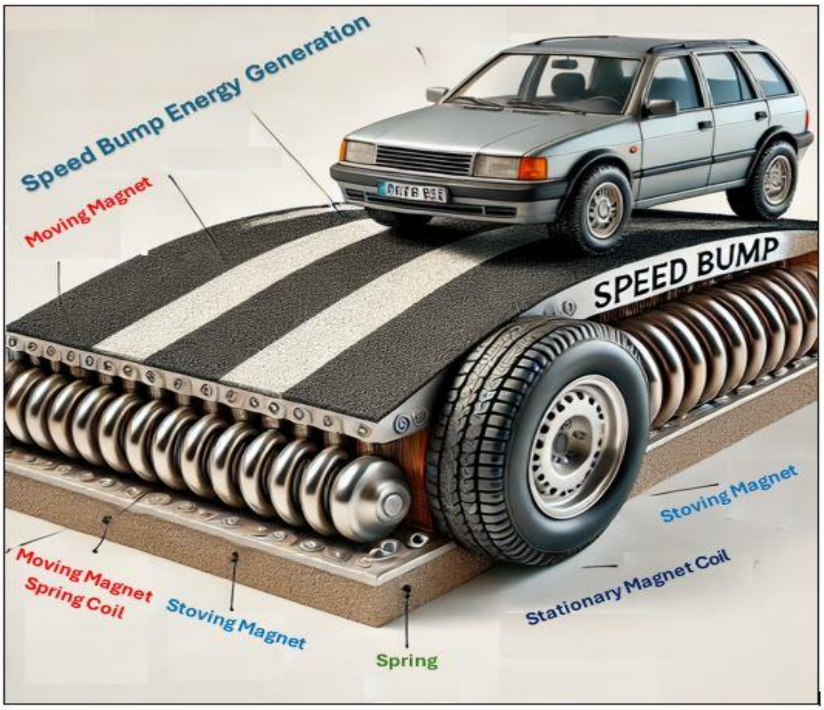

Figure 1: Across sectional view of a speed bump and piezoelectric components

Speed breakers generate mechanical energy by using the vehicle's inertia and converting it into rotational energy via a dynamo. Instead, this paper proposes using an oscillation device that can produce electricity. These energy harvesters can vary the frequency of input vibrations to match electricity demand, making them versatile for various applications. An analytical model shows that the proposed speed breaker can convert a significant portion of energy into electricity by integrating a piezoelectric strip. A multi-degree-of-freedom model studies the electrical and mechanical behavior of the piezoelectric converter attached to the vehicle speed bump, capturing vehicle bouncing dynamics. (Raj et. al.2021)

2.2. Types of Speed Bump Energy Harvesting Systems

More complex systems include a suspension type system and a system in which the energy of the automobile is used to stretch and compress a spring. A system employing magnetorheological fluid is also presented. In addition, a system has been proposed which employs the weights of various moving parts in the internal combustion engine or transmission to generate electricity. This system employs no specialized mechanical components, but still uses the principle of generating electricity as the

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Vol: 61 | Issue: 09 | 2024

automobile stops or slows down because of the bump. Another system proposed makes use of the pitchfork damping motion of the springs of the automobile. Such systems possess both advantages and drawbacks. (Gzal & Gendelman, 2020)

The energy potential of an automobile speed bump is derived from the kinetic energy of the automobile and the action of the automobile in stopping or slowing down as it moves over the bump. Various systems have been proposed for harvesting this energy. The simplest systems consist of massive weights. As an automobile moves over, the up and down motion of the weights due to the action of the automobile in stopping will generate electricity. Blocks are another system type that can be used in a similar manner. (Van Dieu et al., 2022)(Debnath et al., 2023)

3. DESIGN CONSIDERATIONS

A new energy-based traffic-calming speed bump design is needed to convert kinetic energy into electric energy. This could help address energy security issues and reduce reliance on existing energy infrastructures. Energy harvesting from mechanical vibrations or human movements can be used to generate electricity. Roads can also be a source of energy through wind. Researchers have tested an energy-harvesting system that utilizes the frequencies of passing cars and trains. By using a cantilever with a magnet, the system converts displacement into alternating current through electromagnetic induction. This electricity can then be stored for future use. (Wang et al., 2020)

Air suspension road humps in India are designed to slow down vehicles and ensure safe travel in areas with high pedestrian movement. However, hitting these speed breakers can damage wheels and result in an uncomfortable and dangerous ride. The test of endurance for vehicle users highlights the importance of navigating speed breakers carefully. (Samal et al., 2024)

3.1. Materials and Construction

The most significant considerations in the design of the speed bump generator are the selection of the suspension elements to be replaced, how the full energy available from the car can be efficiently dissipated over the length of the speed bump, and how to maintain vehicle stability when traversing the speed bump. The choice of vehicle suspension elements to be replaced is influenced by the view offered by suspension elements, such as the shock absorber, as well as the characteristics that make a location on an urban road a good place to install the generator.

As an example, inductive voice may not be appropriate for stand-alone operation of speed bump generators because ultrasound may be strongly absorbed by excessive air in a humid atmosphere, people may hear the voice, and the system may consume energy to avoid interference with high-frequency audio devices like tracking or security systems. In this work, direct power in the form of rotation power is generated and the vibration frequency is carefully designed to be in humans' audio blind spot and focus the generated audio signal neither at 20 kHz nor in the range between 20 and 60 kHz where most interfered audio devices work. A theoretical and experimental determination of the resonant frequency based on the proposed thin design is reported in Section 4. (Chiu et. al.2024)

3.2. Efficiency and Power Output

Fourth, the property of the helical nonlinear spring, temperature sensitive Ni25CrTiAu shape memory alloy. One side of the helical spring will be attached to the vehicle chassis while the other side of it will be attached to the mass. When the spring is in zero force position, it behaves as if it is 5 cm shorter. This position shall be chosen as the average position of the mass and the spring after some investigation. The way the maximum compression of the spring is chosen is to place the vehicle on the ground and turn the helical spring and block the vehicle (e.g. use a flat wooden platform for the tires to support).

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Vol: 61 | Issue: 09 | 2024

The amount this spring is shortened in this step can be taken as the maximum contraction of the spring. Optimizing these four design parameters for the power output is a challenging and important question for the general case. The parameters need to be optimized for each specific design for optimum power output. (Murphy et.al.2022)(Puchaty et.al.2020) (Pan et al., 2021)

4. CASE STUDIES

Chuayjuljit S and Bukkapatnam STS utilized a piezopatch sensor designed with a highly packed piezoelectric PVDF layer for the field testing of an automobile speed bump used to generate energy. The design was aimed at providing a low-cost system while maintaining the ability to transform energy. To accomplish this, piezopatch sensors of PVDF were constructed with conformal adhesives. The performance of the piezopatch system was tested in both laboratory and field conditions, and the results indicated that the sensor was able to produce energy within feasible vehicle transit velocities, being suitable for the traffic on a rural road. The concept was applied to an electric vehicle to recharge the battery for a short period.

Four BTCUS7 power modules in series were integrated into the piezopatch basic structure. (Salazar et al., 2020) (Iqbal et.al.2022)(Razek, 2023)(Hoseyni et al.2024) Significant charging current was achieved with a state-of-charge battery sensor installed. The piezopatch thickness had to be optimized to provide the best position to transform maximum energy. The most promising application would likely be for vehicles wishing to reduce the load during travel by suppressing the in-built suspension mechanism while undergoing recharging. In this way, stress during travel would be reduced without compromising comfort, leading to the prolonged use of devices while away from a charging station. (Motlagh et al., 2021)(Acar & Motlagh, 2023)

Abid A, Ali H, and Aqsar AR selected a region on campus subjected to a large influx of automobile traffic and poor power system connectivity for the construction of an energy harvesting configuration (Milton-Edwards & Farrell, 2024). The construction was carried out in three main phases. A typical speed bump was constructed with a base slab of Portland cement. After suitable curing and hard set of the slab, the piezoelectric ceramic wafers were placed strategically on the slab and connected to a suitable load for subsequent use.

The setup underwent two months of field testing. During the testing, a typical automobile was used to traverse over the speed bump while the piezoelectric ceramic wafers were excited. The energy harvested was then used to recharge a number of smart portable devices (smartphones, tablets, and so on) for various staff and students. The performance was evaluated via periodic tests involving the recharging of completely drained batteries. At the conclusion of the field test, the setup had demonstrated acceptable periods of device off-grid operation. (Wang et.al.2022)(Wang et al., 2021)

Successful Implementations

The results indicate that the peak voltage values generated by each piezoelectric patch during the compression increase up to 160 V. A power of around 2.7 W has been provided and could be used as an energy source to power road signs, cameras, lights, rectifiers, a temperature sensor, sensors, actuators, etc. The proposed speed hump concept provides speeding and vehicle theft deterrent. Its installation is quick and only requires two anchor bolts.

The dimensions of the current device are suitable for a wide range of automobile chassis sizes. The results show that there are no significant mechanical modifications on the vehicle and the piezoelectric remains at their most efficient permanent performance. (Tommasino et.al.2022) The speed hump has a width of a conventional parking vehicle and consists of a rigid metal frame connected to the ground.

DOI: 10.5281/zenodo.13734589
Vol: 61 | Issue: 09 | 2024

A piezoelectric ceramic is placed at 4 positions to convert the potential energy as several cars pass this speed hump. A vehicle speed of 10 km/h has been considered to measure the piezoelectric generated electricity. Moreover, the maximum impact force during compression has been calculated. (Wang et al., 2023) Heat, noise, and air pollution are some of the major problems arising from an increasing number of automobiles.

However, it is impossible to confine the automobile to their personal vehicle use for daily transportation. Therefore, the sustainable improvement of the energy consumption of road vehicles is a real need to alleviate air pollution. In this paper, we propose that a part of the energy capacity of motor vehicles can be gained by modifying a conventional speed bump and converting the potential energy of a vehicle into electricity. (Wu and Yan2024)(Azam et.al.2021)

5. FUTURE IMPLICATIONS AND CONCLUSION

The exploration of novel energy harvesting technologies plays a significant role in developing sustainable energy solutions. Vehicular traffic flow is ubiquitous and fluctuating; the vehicles traveling on the road generate kinetic energy that is wasted as thermal energy, often dissipating through friction or greenhouse gases when vehicles decelerate or come to a halt. The innovative concept in the research explored the feasibility of reusing and harvesting the wasted kinetic energy by developing an energy-harvesting speed bump.

The main objective of the speed bump design is investigating the amount of generated power over long and high-speed bumps that have subsequent performance implications, as well as identifying a suitable use for the power that was generated to achieve commercially viable products for improving energy efficiency and reducing greenhouse gas emissions.

As global environmental consciousness emerges, the innovation and development of sustainable, clean, alternative energy receive raised scrutiny. This paper contributes by discussing, modeling, and simulating an alternative energy, electricity-generating speed bump system. A real-world implementation is necessary for the validation of the effectiveness and practicality of the speed bump system. Due to the weight of the vehicle, already, the performance power data may be of interest to those who intend to develop such a speed bump system. This invention may be impractical for expressways or highways. In the future, we can conduct validation testing in actual design speed bump installations and create an optimal energy harvesting design structure and control algorithm. (Azam et.al.2021)(Guo and He2020)

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