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Feasibility Study Of Piezoelectric Energy Harvesting In Highway Pavements

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***Abstract*—** Renewable energies are, as we all know, regarded as clean. So credible alternative energy source that reduces CO2, it thus includes renewable energy sources such as wind power Solar, tidal, biomass, and geothermal are all non-hazardous energy sources. The mechanical stress from vehicular movement can be captured by piezoelectric material or cause relative movement in the electromagnetic generator.
Keywords— PZT material, MEMS, ASC, Numerous researchers,

I. INTRODUCTION

The rate of energy consumption has been faster than, than the rate of regeneration of natural natural

resources, the "energy crisis" is just a small example of what will happen to us in the future. Numerous researchers are working on technologies for collecting renewable energies and doing research on increasing the energy collection efficiency of the energy collection system. The demand for electricity will continue to increase as the population increases. Energy harvesting is nothing more than extracting wasted energy from naturally occurring energy sources and then storing it properly for a later period.

II. EASE OF USE

When vehicles run over the energy harvester apparatus, electrical energy can be generated by even mechanical movement after the vehicle has passed, which solves the problem of regenerating energy from pulse vibrations. A design approach and a dynamic model are presented to show the mechanism of action of the energy conversion One of the most critical decisions was how power would be converted from mechanical to electrical. When it comes to power generation, the induction generator is more commonly used because it provides significantly more power due to being more developed and understood**.** Because the rotor of an induction generator is a glorified electromagnet, it would also require an input current to produce power.

The main reasons for using a permanent magnet generator were its size and ease of maintenance. One of the most important aspects of this product is that it fits in the road so that it can do its job. The size must be very small, especially in terms of height, because most layers of pavement are about three inches thick.

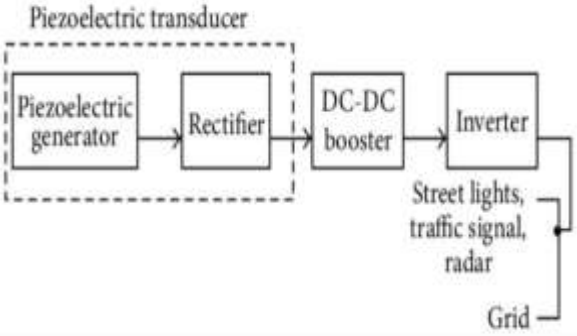
.As one of the most popular types of street energy collectors, many researchers are working on piezoelectric materials. Piezoelectric materials are widely used in energy harvesting field to generate power to power low power consumption equipment. The other popular type of street energy collector is the electromagnetic energy collector. The electromagnetic energy collector generates electricity by absorbing external vibrations in the moving part of the collector. . If the moving part is a magnet, the fixed part of the collector must be a coil and vice versa. The advantages of using electromagnetic energy collectors are that the limitation on collector size is not as critical as it is

with piezoelectric energy collectors. Compared to piezoelectric energy collectors, which must ensure a large contact area or many units in order to generate a large amount of current, the electromagnetic combine harvester can make a unit strong by using strong magnets and a large weight of moving mass. If we look at the performance of a combine, the performance of an electromagnetic combine can be much higher than that of a combine made of piezoelectric material. The electromagnetic collector also generates a relatively high current output. Conversely, most of the electromagnetic energy collector is larger in size than the piezoelectric material collector and generates a relatively low voltage. Since the past few years, people have started showing interest in Sustainable Resources. People are wanting to switch to Electric vehicles that are both cost efficient and environment friendly. Hence, a lot of researchers are wanting to study and research about Electro-Kinetic Roads. As we know, that India really needs to look forward on Sustainable Technology to counter the overuse of fossils.

This Research Based Learning may a better solution for Electro-Kinetic Roads and through this one could also try to identify and overcome the obstacles that the previous researchers have faced in the past during their Research.

Energy harvesting is split into essential groups: macro-electricity harvesting sources, related to solar, wind, hydro, and ocean electricity and micro-electricity harvesting, related to electromagnetic, electrostatic, heat, thermal variations, mechanical vibrations, acoustic and human frame movement as electricity sources..

Different transportation infrastructures are constantly uncovered to distinct electricity sources. From those, it's far viable to extract electricity, which, the usage of precise technology, may be converted into electric electricity. This study pursuits to check the electricity harvesting technology with viable implementation. From the electricity harvesting technology recognized via way of means of Harb corporations of technology(2011), have a remarkable ability for implementation on pavements: one makes use of solar radiation as an electricity supply and the alternative makes use of the mechanical electricity from automobile loads. Considering those electricity sources, unique technology and structures were evolved and been examined in current years. The foremost electricity harvesting technology relevant on street pavement may be divided into foremost corporations, as provided in the first organization is associated with technology that employs the sun publicity on the street pavement. Solar radiation may be immediately harvested via way of means of photovoltaic (PV) and converted into electric electricity; it may set off thermal gradients among the street pavement layers, which may be used to strengthen thermoelectric generators (TEGs), which produce electric electricity, or be harvested via way of means of asphalt sun collectors (ASC), which extract the temperature amassed on the street pavement. Induction heating is an idea wherein introducing conductive debris with inside the asphalt combination offers self- recuperation capacities autonomously at excessive temperatures via way of means of harvesting sun radiation. The 2nd organization is associated with technology that employs the mechanical electricity transferred from cars to the street surface. This may be harvested immediately via way of means of piezoelectric harvesters, which generate electric electricity; or it may be harvested via way of means hydraulic, pneumatic, electromechanical, or micro-electromechanical structures (MEMS) that switch the harvested electricity to electromagnetic generators, which produce electric electricity. In the case of MEMS, the harvested electricity could be switched into piezoelectric generators.



PIEZOELECTRIC ROAD: The roads which produce electricity by application of mechanical energy when vehicle moves over the road, those roads are called as piezoelectric roads

Working of Piezoelectric Sensor

When pressure or acceleration is applied to the PZT material, an equivalent amount of electrical charge gets generated across the crystal faces. Electrical charge will be proportional to the applied pressure. Piezoelectric sensor cannot be used to measure static pressure. At the constant pressure, the output signal will be zero.

In a piezoelectric crystal the charges are exactly balanced in unsymmetrical arrangement also. The effect of the charges cancel out with

each other and hence no net charge will be found on the crystal faces. When the crystal is squeezed, the charge in the crystal becomes unbalanced. Hence, from now on the effect of charge does not cancel with each other which make net positive and negative charge to appear on the opposite faces of the crystal.

Therefore, by squeezing the crystal, voltage is produced across the opposite face and this is known as piezoelectricity.

Fig 1

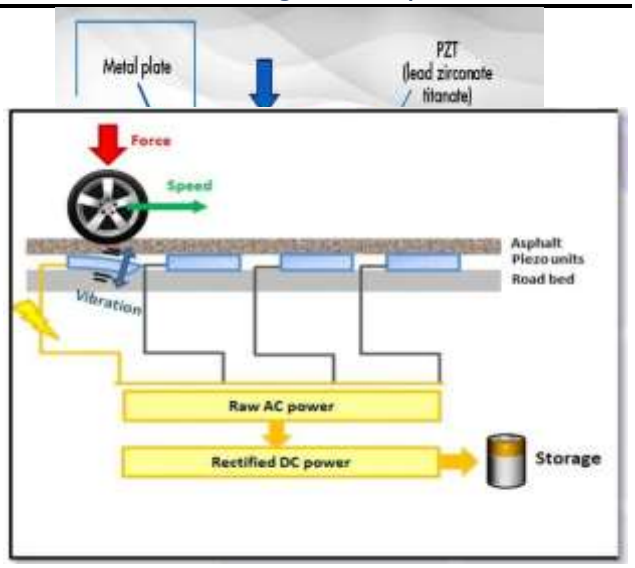
Piezoelectric materials, often in the form of tiles, sensors, or generators, are fixed within the layers of the road surface (typically under the asphalt). They are strategically placed to experience the pressure and vibration from passing vehicles. As vehicles (cars, trucks, bicycles) drive over the road, their weight and movement exert pressure and causes vibrations on the road surface. This mechanical stress or force is transferred to the embedded piezoelectric materials and the resulted compression and vibration causes a charge displacement within the crystal piezoelectric structure .This displacement creates a potential difference across the material. Although, very small current is generated among each pizo cell, but collectively it creates a huge potential.

Fig 2.

- **Harvesting and Storage:**.

The small electrical current generated by each piezoelectric cell is then collected by an integrated energy harvesting system with basic electronic components.

1. Cables and wiring: To carry the generated current.
2. Rectifiers: To convert ac current generated by piezoelectric generator into DC current.
3. DC to DC Booster: To amplify the magnitude of the rectifier



4. Inverter: To convert again the DC output into AC which can be utilized to power the streetlights or later feeded to grid.

Fig 3: actual arrangement

In essence, the piezoelectric cells act as motion sensors or transducers, converting the kinetic energy of moving vehicles into electrical energy. While the amount of energy generated by a single vehicle passing over a small piezoelectric element is relatively small, but the cumulative effect of continuous traffic or moving vehicle flow over a large area of piezoelectric road can potentially generate a significant amount of renewable energy which is a positive breakthrough for sustainable power.

In a growing country like India, road traffic and congestion on the roads is a huge problem. The vehicles running over the roads during traffic are in large numbers, thus the stress and energy dissipated to the immediate layers of pavement get wasted. A solution is necessary to solve these problems with the probe of smart infrastructure in association with communication and ITS, the Intelligent Transportation System which is a step toward being a developed and technologically upgraded nation.

The best solution for making ideal use of this energy ,we can build kinetic roads which use piezoelectric sensors which help in producing electricity due to the mechanical stresses experienced by the roads.

Key aspects of Intelligent Transportation Systems include:

- Integration of Technologies: Various technologies are combined in it such as sensors, communication networks, data analytics, and real-time monitoring.
- Improved Efficiency and Mobility: ITS aims to optimize traffic flow, reduce

congestion, and improve overall travel times for people and goods.

- Enhanced Safety: Many ITS applications focus on preventing accidents, providing warnings, and improving response times in emergency situations.
- Sustainability: ITS can contribute to reducing emissions and promoting more environmentally friendly transportation options.
- Real-time Information: Providing timely and accurate information to travellers is a core function, allowing them to make informed decisions about their journeys.

Various ITS applications include:

Adaptive traffic signals, incident detection, and congestion management.

Real-time traffic updates, route guidance, and public transport information via apps and variable message

Key Aspects and Considerations:

Piezoelectric Materials: Various piezoelectric materials can be used, including Cyramics,Crystala,Polymers.

- Ceramics: Lead Zirconate Titanate (PZT) is a common choice due to its high piezoelectric coefficient.
- Crystals: Quartz is a naturally occurring piezoelectric crystal.
- Polymers: Polyvinylidene Fluoride (PVDF) offers flexibility.

- Placement and Design: Piezoelectric generators or sensors can be embedded in different layers of the road structure or placed on the surface. The design and placement are crucial for maximizing the mechanical stress transferred to the piezoelectric elements.
- Energy Output: The amount of electricity generated depends on factors such as:

- Traffic volume and weight: Higher traffic density and heavier vehicles result in more mechanical stress.

- Vehicle speed: Speed influences the frequency and magnitude of vibrations.
- Type and amount of piezoelectric material: Materials with higher piezoelectric coefficients generate more charge.
- Design and efficiency of the harvesting system: Efficient collection and conditioning of the generated electricity are essential.

Challenges and Limitations:

1) Low Power Output**:** A significant challenge is the relatively low amount of power generated per vehicle pass.

2) Piezoelectric materials embedded in roads must withstand harsh environmental conditions (temperature variations, moisture, heavy loads) and maintain their performance over long periods

3) The initial cost of piezoelectric materials and the installation process can be high.

4) The efficiency of converting mechanical energy to electrical energy can be limited.

5) Energy losses can occur during the mechanical-to-electrical conversion process due to the material's hysteresis. 6) Seamless integration without compromising the structural integrity of the road is crucial.

Potential and Future:

Despite the challenges, piezoelectric road technology holds promise as a sustainable energy harvesting solution, particularly for localized power needs along roadways. Ongoing research focuses on developing more efficient piezoelectric materials, optimizing system designs, and reducing costs to make this technology more viable for widespread implementation within Intelligent Transportation Systems (ITS).

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