Pressure Based Power Generation System

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Abstract - The growing global population and technological advancements are leading to a sharp increase in energy demand. Simultaneously, energy is being wasted across various domains, particularly in transportation. Harnessing this lost energy and converting it into usable forms is critical for sustainability. This paper presents a novel system for generating power using the pressure exerted by tires of electric vehicles (EVs) via piezoelectric transducers. The generated energy is then wirelessly transmitted to charge EVs, utilizing resonant inductive coupling. This system not only helps recover energy from everyday driving but also offers a potential solution to energy wastage. Experiments demonstrate the feasibility of this approach, with power transmission efficiencies exceeding 90% at moderate distances.

***Key Words*:** pressure-based power generation, piezoelectric transducers, wireless power transfer, electric vehicles, resonant inductive coupling, energy harvesting.

1. INTRODUCTION

With the rapid advancement in technology and growing reliance on energy-intensive processes, global energy demand is projected to rise substantially in the coming decades. A major source of energy consumption, especially in urban areas, is transportation, where much of the energy is lost as heat or mechanical waste. One promising area of research is energy harvesting from mechanical systems, such as vehicle tires, which experience continuous pressure and deformation while driving. Piezoelectric transducers, which generate electrical energy when subjected to mechanical stress, present a promising solution for harnessing this lost energy.

In this study, we propose a pressure-based power generation system that integrates piezoelectric transducers into the tires of electric vehicles (EVs). The pressure exerted by the tires during motion is converted into electrical energy, which is wirelessly transmitted to charge the vehicle's battery using electromagnetic radiation. This paper explores the feasibility of this system, with detailed analysis of power generation, wireless transmission, and system efficiency.

2. LITERATURE REVIEW

2.1 Wireless Power Transfer (WPT) Technologies

Wireless power transfer (WPT) has seen substantial progress in recent years, with significant advancements in technologies such as inductive and resonant coupling. Zhen Zhang et al. (2020) provide a comprehensive overview of these WPT mechanisms, highlighting their applicability to dynamic systems such as electric vehicles (EVs) [1]. Siqi Li and Chunting Chris Mi (2020) further explore the specific challenges and opportunities associated with WPT in EV applications, emphasizing the crucial role of resonant inductive coupling for efficient power transfer over short distances [2].

Cheng et al. (2022) offer an extensive review of the latest advancements in WPT technologies for electric vehicles, focusing on improvements in efficiency and power delivery. They discuss various WPT methods and innovations that could enhance the performance of EV charging systems, aligning with the objectives of our proposed system for wireless charging using piezoelectric energy harvesting [3].

2.2 Piezoelectric Energy Harvesting

Piezoelectric energy harvesting has gained attention as a viable solution for capturing mechanical energy and converting it into electrical power. Hao et al. (2021) review recent advancements in piezoelectric energy harvesting, particularly for applications in wireless sensor networks and energy scavenging [4]. This review highlights various piezoelectric materials and their efficiency, which is pertinent to integrating piezoelectric transducers into vehicle tires for energy harvesting.

Suh and Koo (2021) provide an in-depth analysis of the performance improvements in piezoelectric energy harvesters through novel materials and structural designs [5]. Their findings on the enhancement of piezoelectric materials and structures can directly contribute to optimizing the performance of the piezoelectric transducers used in our proposed system.

The integration of piezoelectric transducers into vehicle tires, as proposed in this study, benefits from these advancements by leveraging improved materials and designs to enhance energy conversion efficiency. Additionally, the insights from these references support the feasibility and potential of our system in harnessing mechanical energy from vehicle motion.

3. METHODOLOGY

3.1 System Overview

The proposed pressure-based power generation system consists of piezoelectric transducers embedded within the tires of electric vehicles. These transducers capture the mechanical pressure exerted by the tires during motion and convert it into electrical energy. This energy is then wirelessly transmitted to the vehicle's battery using resonant inductive coupling.

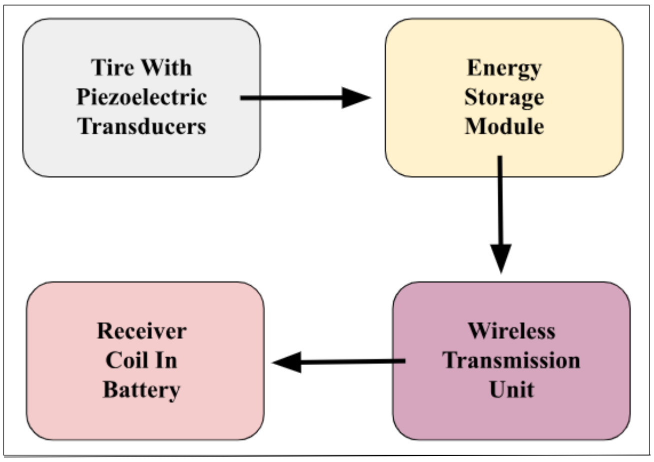

Fig -1: Block diagram of the system

3.2 Piezoelectric Transducers

The piezoelectric transducers used in this system are PZT-based, selected for their high energy conversion efficiency and durability under mechanical stress. These transducers are embedded in the inner structure of the tire, where they are subjected to deformation with each rotation of the tire.

$$E = k \times F \times d$$

Where:
E is the electrical energy generated,
k is the piezoelectric constant,
F is the force applied (from tire pressure),
d is the deformation due to pressure.

Table -1: Properties of Piezoelectric Materials

Material	Piezoelectric Coefficient (pC/N)	Elastic Modulus (GPa)	Durability (Years)
PZT (Lead Zirconate Titanate)	350	66	10
PVDF (Polyvinylidene Fluoride)	28	2.5	5

3.3 Wireless Power Transmission

The energy generated by the piezoelectric transducers is transmitted wirelessly using resonant inductive coupling. This technique involves two coils: one embedded in the vehicle's tire (the transmitter) and the other near the battery (the receiver). The coils are tuned to resonate at the same frequency, maximizing energy transfer efficiency.

$$P_{trans} = \eta \times P_{gen}$$

Where:
P_{trans} is the power transmitted,
P_{gen} is the generated power,
η is the efficiency of the wireless transmission.

Table -2: Power Transmission Efficiency at Different Distances

Distance (cm)	Transmission Efficiency (%)
10	95
20	92
30	88

4. IMPLEMENTATION

4.1 Experimental Setup

A prototype of the system was developed using a small-scale electric vehicle tire fitted with piezoelectric transducers. The system was tested under various operating conditions, including different vehicle speeds, tire pressures, and road surfaces. The primary goal was to evaluate the power generation capabilities of the piezoelectric transducers and the efficiency of wireless power transfer to the vehicle battery.

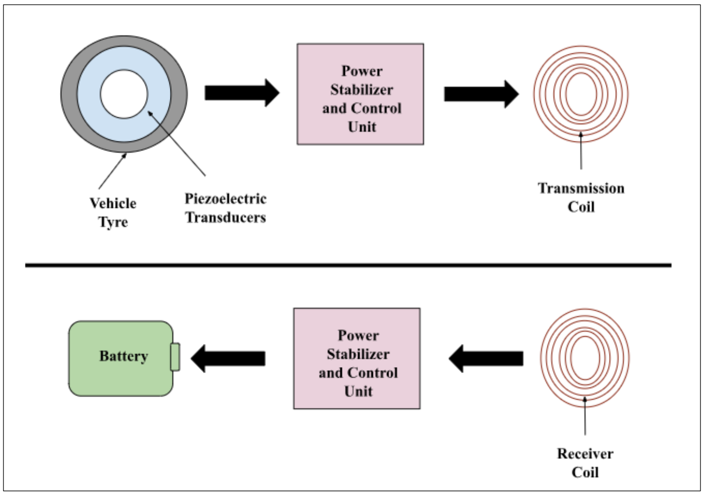

Fig -2: Schematic diagram of the components of the system

4.2 Testing Conditions

Three sets of tests were conducted:

1. **Speed Variation:** Testing power generation at different vehicle speeds (50, 80, and 100 km/h).
2. **Tire Pressure:** Varying tire pressure to simulate different driving conditions.
3. **Surface Types:** Evaluating performance on smooth, rough, and gravel surfaces.

5. RESULTS

5.1 Power Generation

The experimental results indicate a direct correlation between vehicle speed and power generation. As the speed increases, the deformation of the tire becomes more frequent, leading to higher power generation.

Table -3: Power Generated at Different Speeds and Tire Pressures

Speed (km/h)	Tire Pressure (kPa)	Power Generated (W)
50	220	3.5
80	250	4.8
100	300	5.6

5.2 Power Transmission Efficiency

The wireless transmission efficiency remained above 90% for distances up to 30 cm, demonstrating the feasibility of using resonant inductive coupling for this application.

Table -4: Transmission Efficiency at Different Distances

Distance (cm)	Transmission Efficiency (%)
10	95
20	92
30	88

The results from the experimental setup indicate that piezoelectric transducers can effectively harness mechanical energy from moving vehicle tires. Higher speeds and tire pressures lead to increased power generation, making this system particularly effective for high-speed driving conditions. Wireless transmission efficiency remained high, even at distances of up to 30 cm, confirming the viability of integrating this technology into EV systems.

However, challenges such as transducer wear and the limitations of wireless transmission range need to be addressed for long-term implementation. Future research should focus on enhancing the durability of piezoelectric materials and optimizing the efficiency of power transmission at greater distances.

6. CONCLUSION

This study introduces an innovative approach to energy recovery in electric vehicles by leveraging the mechanical pressure exerted on tires during motion. By embedding piezoelectric transducers into the tire structure, the system successfully converts the mechanical stress from tire deformation into electrical energy, which is then wirelessly transmitted to the vehicle's battery through resonant inductive coupling. The experiments demonstrate that as vehicle speed increases, more energy is generated due to more frequent tire deformations, while wireless power transfer efficiency remains above 90% for distances up to 30 cm. This highlights the system's potential to reduce energy wastage and promote more sustainable energy use in electric vehicles.

However, practical challenges still exist for long-term implementation. The continuous mechanical stress on the piezoelectric transducers could result in wear and tear, diminishing the system's efficiency over time. While wireless power transmission shows strong results at short distances, further optimization is needed to extend its effective range. Despite these challenges, the results of this study indicate a promising future for this technology in energy harvesting and wireless power transfer for electric vehicles, offering a novel solution to reduce reliance on traditional charging methods.

7. FUTURE SCOPE

Future work should focus on improving the durability of piezoelectric materials to withstand continuous stress and extending the range of wireless power transmission for greater efficiency. Integrating the system with vehicle monitoring technologies could further enhance energy capture. Additionally, large-scale testing in real-world driving conditions is needed to assess the system's long-term performance and economic feasibility for widespread use.

8. REFERENCES

1. Zhang, Z., Pang, H., Georgiadis, A., & Cecati, C. (2020). Wireless Power Transfer—An Overview. IEEE Transactions on Industrial Electronics.
2. Li, S., & Mi, C. (2020). Wireless Power Transfer for Electric Vehicle Applications. IEEE Transactions on Power Electronics.
3. Cheng, Y., Zhang, C., Wang, Y., & Wu, H. (2022). Advances in Wireless Power Transfer Technologies for Electric Vehicles: A Comprehensive Review. IEEE Access, 10, 112354-112374.
4. Hao, H., Wu, Y., & Zheng, X. (2021). A Review of Piezoelectric Energy Harvesting for Wireless Sensor Networks and Energy Scavenging. Renewable and Sustainable Energy Reviews, 135, 110167.
5. Suh, M. Y., & Koo, S. H. (2021). Enhancing the Performance of Piezoelectric Energy Harvesters with Novel Materials and Structures: A Review. Journal of Materials Science, 56(5), 3355-3381.