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TIREVOLT: MOTION POWERED WIRELESS CHARGING FOR EV VEHICLES

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Abstract: The road transport sector's reliance on conventional fuels has significant energy and environmental implications, contributing to greenhouse gas emissions and climate change. To mitigate these effects, innovative solutions are necessary to reduce emissions and promote sustainable transportation. This project, TireVolt, focuses on developing a self-charging capability for electric vehicles by harnessing kinetic energy from vehicle motion, including tire rotation, to power wireless charging. By leveraging electromagnetic induction, TireVolt converts kinetic energy into electrical energy, enabling electric vehicles to generate their own power and reducing reliance on external charging infrastructure. This self- sustaining energy loop has the potential to increase energy efficiency, reduce emissions, and enhance the overall driving experience, making electric vehicles more practical, efficient, and environmentally friendly.

Index Terms: Wireless charging, Sustainable transportation, Electric vehicles, Kinetic energy harvesting.

I. INTRODUCTION

The transportation sector is a vital component of the global economy, with road transport being a significant contributor to energy consumption and greenhouse gas emissions. The increasing demand for energy and the environmental concerns associated with traditional fossil fuel-based transportation systems have led to a growing interest in sustainable and innovative solutions. Electric vehicles (EVs) have emerged as a promising alternative, offering a cleaner and more environmentally friendly option for transportation. However, the widespread adoption of EVs is hindered by limitations in charging infrastructure and range anxiety. To address these challenges, this project, TireVolt, focuses on developing a self-charging capability for electric vehicles by harnessing kinetic energy from vehicle motion, including tire rotation, to power wireless charging. By leveraging electromagnetic induction, TireVolt enables EVs to generate their own energy, reducing reliance on external charging infrastructure and promoting a more sustainable transportation ecosystem.

This innovative approach has the potential to increase energy efficiency, reduce emissions, and enhance the overall driving experience. The development of TireVolt represents a significant step towards a more sustainable and environmentally friendly transportation ecosystem, where electric vehicles can operate with greater autonomy and reduced environmental impact. By exploring energy harvesting technologies and their applications in vehicles, this project aims to contribute to the development of more efficient, eco-friendly, and self-sustaining transportation solutions.

The context of this project lies in the pressing need for sustainable transportation solutions, driven by the environmental concerns and energy demands associated with traditional fossil fuel-based transportation systems. The focus of TireVolt is on harnessing kinetic energy from vehicle motion to develop a self-charging capability for electric vehicles, thereby reducing reliance on external charging infrastructure and promoting a more sustainable transportation ecosystem. By exploring energy harvesting technologies and their applications in vehicles, this project aims to contribute to the development of more efficient, eco-friendly, and self- sustaining transportation solutions, ultimately transforming the transportation sector and promoting a more sustainable future.

II. LITERATURE SURVEY

The paper by S. P. Beeby et al [1] provides a foundational review of micro-scale energy harvesting techniques, especially piezoelectric, electromagnetic, and thermoelectric types. Their work highlights the promise of each approach for powering sma ll- scale electronics, but notes the inconsistent energy output and practical integration difficulties of piezoelectric and thermoelectric harvesters, especially in dynamic systems.

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S. Priya and D. J. Inman [2] examine advances in piezoelectric harvesting technologies. Their paper emphasizes improvements in energy density and integration into wearable and structural health monitoring systems. However, they also acknowledge significant challenges like fragility under mechanical loads, frequency mismatch, and low efficiency in environments with irregular vibrations.

D. Paul et al [3] evaluate real-world applications of piezoelectric materials, particularly their transformation from lab prototypes to practical deployments. The paper outlines the benefits of piezoelectrics in low-power settings but critiques their sensitivity to external factors like humidity and temperature, which limit their long-term performance and scalability in vehicles or mobile systems.

The paper by A. K. Yakimov et al [4] investigates mechanical properties of materials under dynamic loads. Although focused on hovercraft applications, the methods of analyzing tensile and flexural stress are applicable to moving systems like rotating wheels. Their findings assist in selecting resilient materials for coil housing in energy harvesters integrated into vehicles.

K. Bhatt et al [5] perform a comparative analysis of energy harvesting techniques—piezoelectric, thermoelectric, and electromagnetic. They find electromagnetic harvesting most suitable for systems in motion, citing its scalability, reduced wear and tear, and high compatibility with rotational applications such as vehicle tires.

D. Yildirim et al [6] propose a magnetic levitation-based electromagnetic energy harvester to reduce mechanical contact and enhance efficiency. The results show improved power output and durability compared to traditional electromagnetic harvesters, aligning well with the needs of tire-based, continuous-motion systems.

P. Thirupathi [7], in his thesis, designs an electromagnetic harvester for vehicle wheels, detailing the coil and magnet arrangement to capture rotational energy. His experimental validation confirms its feasibility for low-power generation, making it highly relevant to self-charging electric vehicle concepts.

S. Herrador [8] focuses on hybrid energy harvesting using combined piezoelectric and thermoelectric modules. His study concludes that individual methods often fail to meet energy demands, and recommends integration with electromagnetic systems for better consistency and reliability in motion-based applications.

D. J. Domme [9] investigates a vibration-based electromagnetic transducer. His experiments show that such transducers can achieve stable energy output over time, especially in environments with repetitive motion—like those found in rotating tires or mechanical suspensions.

P. Ben-Abdallah and S.-A. Biehs [10] explore a novel method of energy harvesting using near-field electromagnetic thermal radiation. While largely theoretical, their analysis suggests potential for future ultra-compact energy harvesters, pushing the boundaries of electromagnetic applications in tight or embedded systems.

R. A. Powar and A. S. Manjarekar [11] assess piezoelectric energy harvesting on roadways, finding it inefficient due to mechanical degradation and low conversion rates. They suggest transitioning to non-contact methods like electromagnetic induction, which offer better durability and output under high-traffic conditions.

P. S. Goyal [12] continues this critique, showing that piezoelectric systems are heavily dependent on material selection, precise vibration tuning, and environmental control—factors hard to maintain in vehicular systems, thus motivating the shift toward electromagnetic-based solutions.

C. Bach [13] reports on successful deployment of magnetic induction-based sensors on high-voltage power lines. These systems, operating autonomously using harvested energy, demonstrate the robustness and efficiency of electromagnetic systems in long- term real-world environments, validating their suitability for vehicular energy systems.

Y. Yang et al [14] present a study on broadband electromagnetic energy harvesters designed to work over multiple vibration frequencies. Their design ensures consistent power output even with variable motion patterns, an advantage when applied to moving vehicles experiencing different speeds and road textures.

N. Prasad [15] proposes a hybrid energy harvester using thermal, optical, and electromagnetic methods. His analysis concludes that electromagnetic induction provides a stable base for such hybrid systems due to its low maintenance and scalability, reinforcing the direction of using electromagnetic methods for self-charging applications in dynamic

systems.
Naik et al.[16]conducted a comprehensive review on the use of composite materials for energy harvesting in electric vehicles. Their study highlights the potential of composites in enhancing energy efficiency and sustainability in EVs. However, they also note challenges related to material selection and integration into existing vehicle systems.

Akshayveer et al.[17] explored environment-friendly technologies utilizing lead-free piezoelectric materials. They emphasize the importance of developing sustainable materials for energy harvesting applications, particularly in the context of environmental and health concerns associated with traditional lead-based piezo electrics. The authors also discuss the need for advanced modeling approaches to optimize the performance of these materials.

Caban et al.[18]provided an overview of various energy harvesting technologies employed in road vehicles. Their research categorizes different methods, including electromagnetic and piezoelectric systems, and assesses their applicability in automotive contexts. The study underscores the importance of selecting appropriate harvesting techniques based on specific vehicle requirements and operational conditions.

Zhang et al.[19] investigated the design and implementation of a small-scale long-distance RF energy harvesting system for wireless charging. Utilizing advanced machine learning techniques such as CNN, LSTM, and reinforcement learning, they developed a system capable of efficient energy capture and management. While promising, the complexity of integrating such systems into existing EV infrastructure remains a challenge.

Kadiravan et al.[20] examined electromagnetic energy harvesting technologies for roadways, focusing on harnessing sustainable power from traffic. Their study discusses the correlation between traffic parameters and energy generation, highlighting the potential of integrating such systems into urban infrastructure. However, considerations regarding environmental impact and policy implementation are crucial for widespread adoption.

Latha et al.[21] analyzed various wireless power transfer compensation topologies to enhance electric vehicle charging. Their research provides insights into optimizing power transfer efficiency and discusses the implications of different compensation methods. The study contributes to the development of more effective wireless charging solutions for EVs.

Tabak etal.[22] reviewed piezoelectric energy-harvesting structures utilizing auxetic materials. They found that incorporating auxetic structures can significantly improve energy harvesting efficiency due to their unique mechanical properties. The research suggests that these materials could play a vital role in advancing energy harvesting technologies for automotive applications.

Gupta etal.[23] explored composite materials for energy harvesting in electric vehicles, emphasizing their mechanical and electrical properties. The study discusses the suitability of various composites in energy harvesting systems and addresses challenges related to durability and cost. The authors advocate for continued research to enhance the reliability of these materials in practical applications.

Kobbi etal.[24] reviewed energy harvesting technologies in electric vehicles, focusing on their applications in sustainable agricultural transportation. They analyzed various techniques, including solar energy harvesting, regenerative braking, and vibration energy harvesting, discussing their advantages and limitations. The study highlights the potential of these technologies to improve driving range and support sustainable practices in agriculture.

Kang[25] presented approaches toward efficient piezoelectric-based energy harvesting, introducing hybrid systems combining piezoelectric and electromagnetic mechanisms. His research demonstrates the potential of these hybrid systems to generate significant electricity in vibration-rich environments, such as roadways. The study also explores the application of PVDF-based piezoelectric harvesters in road infrastructure.

III. CONCLUSION

The reviewed literature highlights the evolution and comparative performance of various energy harvesting methods, including piezoelectric, thermoelectric, and electromagnetic systems. Among these, electromagnetic induction consistently emerges as the most viable and efficient technique for dynamic environments such as rotating vehicle wheels. Studies emphasize its scalability, durability, and ability to generate consistent power output in motion-based systems—qualities essential for self-charging electric vehicles. Furthermore, the limitations of piezoelectric and thermoelectric methods, including sensitivity to environmental factors and structural fragility, reinforce the selection of

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electromagnetic systems for this application.
The integration of rotating magnets and stationary coils has already demonstrated practical feasibility in related studies, validating the core design of the proposed TireVolt system. The literature collectively supports the direction of this project by providing strong technical justification for using motion-powered electromagnetic induction to enable autonomous, wireless charging in EVs.This foundation enables TireVolt to move confidently toward a sustainable, efficient, and self-reliant energy solution for modern electric mobility.

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