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Footstep Power Generation using Piezoelectric Sensor

[1]Ganesh Korwar, [2] Sunil Shinde, [3]Shreya Channawar, [4]Sanika Benke, [5]Charvi Potdar
[1]Mechanical Department
[1]Vishwakarma Institute of Technology, Pune, India

Abstract - The Piezoelectric sensors have gained significant attention owing to their ability to convert mechanical energy into electrical signals. This paper proposes a novel application of piezoelectric sensors integrated with light-emitting diodes (LEDs) to create a responsive and energy-efficient illumination system. The primary objective of this research is to explore the feasibility and effectiveness of utilizing piezoelectric sensors to trigger LED glow in various scenarios. Overall, this research contributes to the advancement of sensor-driven illumination systems by leveraging the unique properties of piezoelectric materials. The proposed technology offers promising prospects for enhancing sensing capabilities and promoting energy conservation in various real-world applications.

Keywords- Piezoelectric Sensors, Power Generation, Non-conventional renewable energy

I. INTRODUCTION -

Our world is constantly buzzing with unused energy – the vibrations from footsteps, traffic, or even wind gusts. Piezoelectric technology offers a way to capture this energy and convert it into something useful, like light! This project explores how a piezoelectric sensor can be used to generate electricity and illuminate an LED. Piezoelectric materials possess a unique property. When compressed or vibrated, their internal structure creates a tiny voltage. This project harnesses this voltage by using a piezoelectric sensor. As pressure or vibrations are applied to the sensor, it generates a small amount of electricity.

Now a day's energy is one in all the foremost necessary problems round the world. Renewable energy sources may be an excellent medium to unravel this energy crisis drawback. As we, all know natural resources can end in the future; researchers try to introduce substitute energy sources from nature. That has to be inexperienced and not harmful to the setting. Natural processes with continuous renewal obtain renewable energy. There is wasted energy all over. An enormous variety of individuals walking, jogging, and running each day generate huge energy that is simply a loss. The compression and bending of the shoe sole represent some way for gather energy that would be place to helpful applications. Composition electricity plates within the sole of a shoe, there is an opening to regain an even quantity of energy.

II. NEED OF SYSTEM -

The utilization of energy generated from human motion and foot traffic has become increasingly important in highly populated countries like India and China. These nations, characterized by their dense populations, experience immense footfall in public spaces such as railway stations, temples, marketplaces, and sidewalks, where millions of people move around the clock. Harnessing this kinetic energy offers a sustainable solution to meet the rising energy demands in an eco-friendly manner.

The continuous movement of pedestrians in crowded areas provides a renewable and consistent source of power, which, when converted into electrical energy, reduces reliance on conventional fossil fuels and minimizes the carbon footprint.

Such systems are particularly relevant in addressing energy shortages, especially in regions with frequent power outages, by offering localized and cost-effective solutions for powering lighting, signage, and small devices.

Advances in technologies like piezoelectric materials and electromagnetic energy harvesting have made these systems more feasible and efficient, allowing seamless integration into existing infrastructure. Furthermore, they present an opportunity to utilize otherwise wasted energy, turning everyday activities like walking into a productive resource. By promoting sustainability, reducing environmental impact, and generating awareness about renewable energy, these systems not only align with global goals for clean energy but also stimulate economic growth by creating jobs in their development and deployment. Their implementation in densely populated regions can revolutionize energy production while addressing environmental and social challenges effectively.

III. METHODOLOGY

A. Basic Principle of Piezoelectric Sensor:

This section will outline the steps involved in creating a system that uses a piezoelectric sensor to generate electricity and power an LED light. The first and the most important system is an electricity device. There are four piezoelectric sensors used.

Piezoelectricity is current created from mechanical pressure with the assistance of electricity sensors. Electricity materials have two properties that are outlined as a right away and converse result. The direct result is that the property of some materials to develop charge on their surface once mechanical stress is exerted on them, whereas the converse result is that the property of some materials to develop mechanical stress once an electrical charge is evoked. Within the Converse result, once the pressure is applied to associate degree object, a charge is created on the dilated facet and a charge on the compressed facet of the crystal. Once the pressure is mitigated, electrical current flows across the fabric.

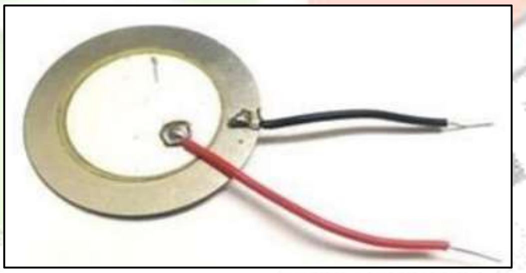

Fig.A. Piezoelectric sensors

B.LED-

In our project, we employ Light Emitting Diodes (LEDs) in conjunction with four piezoelectric sensors. These sensors serve the function of converting pressure or mechanical stress into electric energy. The generated electrical charge is then utilized to power the LED. This setup harnesses the principle of piezoelectricity, where certain materials produce an electric charge in response to applied mechanical stress.

Fig.B. LED

C.Unidirectional diode-

Additionally, a unidirectional diode can also be integrated into the project setup. The diode ensures that the flow of electrical current is restricted to one direction, preventing reverse current flow. This feature safeguards the components, particularly the LED, from potential damage due to reversed polarity or unintended electrical feedback. By enforcing a unidirectional flow, the diode enhances the reliability and longevity of the system, contributing to its overall stability and performance.

Fig.C. Unidirectional Diode

D. Battery (3.5 V)-

The 3.5V battery serves as a vital energy source for our project. Its stable voltage output ensures consistent operation of the LED and facilitates the piezoelectric sensors' functionality. The battery's compact size and portability make it an ideal power solution for our setup, enabling flexibility in deployment and usage scenarios. Its longevity and reliability ensure prolonged operation without the need for frequent replacements, enhancing the overall efficiency and sustainability of the project.

Fig.D. Battery 3.5V

IV. Objective -

This research aims to investigate the potential of harnessing energy from human footsteps by embedding piezoelectric sensors within the soles of shoes. The primary focus is on developing and implementing a system that can effectively convert the kinetic energy generated during walking into electrical energy, offering a portable and sustainable source of power. The study explores how piezoelectric materials, known for their ability to produce an electrical charge in response to mechanical stress, can be integrated into wearable technology, transforming the energy from human motion into a usable form.

A key aspect of this research is optimizing the design and placement of the piezoelectric sensors to maximize energy conversion efficiency while ensuring comfort and practicality for the user. The study also examines the feasibility of applying this technology in real-world scenarios, such as powering small electronic devices or supplementing energy needs in resource-limited environments. By evaluating the performance, durability, and scalability of this system, the research seeks to address challenges associated with energy harvesting from motion and provide a foundation for future advancements in this field.

Ultimately, this work aims to demonstrate the practicality of generating electricity from everyday human activities, contributing to the development of renewable energy solutions and advancing wearable technologies. By tapping into the energy of human motion, the study not only underscores the potential of sustainable energy generation but also paves the way for innovative applications in portable and self-sufficient energy systems.

In summary, this research successfully addresses the objective of evaluating the potential to generate energy from human footsteps using piezoelectric sensors embedded in shoes. The study highlights the practicality of transforming the kinetic energy generated during walking into electrical energy, offering a novel and sustainable method of power generation. Through the design and implementation of a working system, this research provides a basis for incorporating energy-harvesting technology into wearable devices. The outcomes open doors for future innovations in renewable energy, emphasizing the role of human motion in creating environmentally friendly and portable energy solutions.

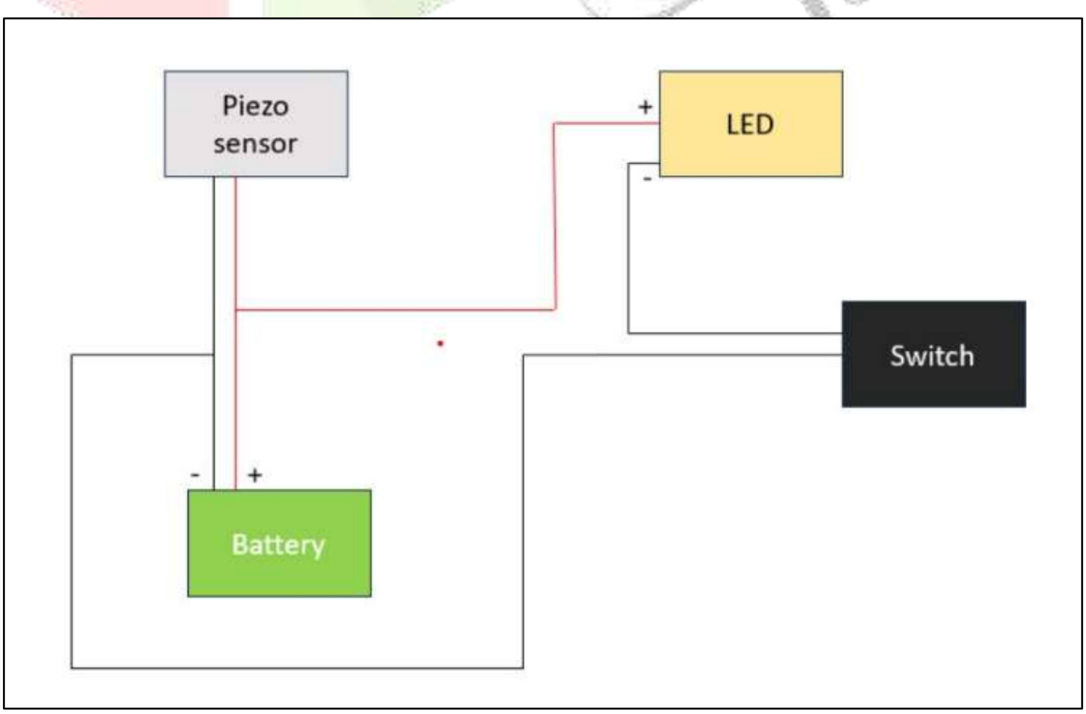

Fig. C. Circuit diagram

V. Experimental Setup -

The experimental setup was carefully designed to harness energy from human footsteps using piezoelectric sensors embedded within the soles of shoes. To achieve this, several components were assembled to create a functional prototype capable of converting mechanical energy from walking into electrical power.

- **Shoe Sole**: The shoe sole acts as the foundation for the system, providing the necessary platform to house the piezoelectric sensors. It is essential that the sole is sturdy and capable of withstanding the mechanical stress exerted by each step, while also allowing for effective integration of the sensors without compromising comfort or functionality.

- **Piezoelectric Sensors**: Four piezoelectric sensors were strategically placed within the sole to capture the mechanical stress generated during walking. These sensors were chosen for their ability to generate an electrical charge when subjected to pressure or deformation. By positioning the sensors at key points within the sole, we aimed to maximize energy harvesting efficiency from the natural motion of walking.

- **Cell (Battery)**: A rechargeable lithium-ion battery was selected to store the electrical energy generated by the piezoelectric sensors. The lithium-ion battery was chosen due to its high energy density, long cycle life, and ability to efficiently store and release power. This ensures that the energy captured during walking is stored for later use, such as powering small devices or serving as a backup power source.

- **Jumper Wires**: Jumper wires were used to create the electrical connections between the piezoelectric sensors, battery, and other components. These wires facilitated the transfer of the generated electrical energy to the storage unit and ensured that all components were securely interconnected, allowing for proper functioning of the system.

- **LED Indicator**: An LED indicator was incorporated into the setup to visually demonstrate the generation and flow of electrical power. The LED would light up when energy was generated, providing immediate feedback on the system's performance and showing the efficiency of energy conversion in real-time.

- **Switch**: A switch was included to manage the flow of electricity, providing the ability to conserve energy when the system was not in use. This feature allows the user to control when the system is active and ensures that the stored energy is not depleted unnecessarily, optimizing the overall efficiency of the power-generating shoe system.

Calculation and Analysis-

In this phase, detailed calculations were performed to estimate the potential energy generation from each step. The calculations took into account several key factors, including the weight of the individual, the acceleration due to gravity, and the displacement caused by the foot during walking. By understanding the force exerted during each step and analysing the properties of the piezoelectric sensors, we were able to determine the amount of energy generated per step. This data was then extrapolated to estimate the total energy production over a specific number of steps, providing a clear picture of the system’s potential energy output in various walking scenarios. The calculations also helped in fine-tuning the placement of the sensors to ensure optimal energy harvesting.

Prototype Development-

Using the calculations and design specifications, we proceeded to develop a prototype of the power-generating shoe system. This involved embedding the piezoelectric sensors into the soles of the shoes at strategic locations where the maximum mechanical stress occurs during walking. The wiring was carefully installed to connect the sensors to the rechargeable battery and other components, such as the LED indicator.

The integration of these components was done in a way that maintained the overall comfort and usability of the shoe, while ensuring that the system was capable of efficiently converting and storing energy.

Testing and Evaluation-

Once the prototype was assembled, it underwent thorough testing to evaluate its performance and effectiveness in generating electricity during walking. Several testing scenarios were designed to assess how the system performed under different walking conditions, such as varying walking speeds, different types of surfaces (e.g., concrete, grass), and various environmental conditions. These tests allowed for the collection of valuable data on key parameters such as voltage, current, and power output. By analysing the data, we were able to validate our initial calculations and refine the design to improve efficiency and reliability. The results of the testing phase provided insights into the system's robustness, helping us identify potential areas for improvement and ensuring that the prototype was capable of generating a consistent power output over time.

This comprehensive testing and evaluation process allowed us to assess the overall viability of the power-generating shoe system and to ensure that it met the desired performance standards. The data gathered during testing also served as a foundation for future developments and optimizations of the system, ensuring that it could be applied effectively in real-world scenarios.

VI. PROTOTYPE-

Fig a. Image representing all connections

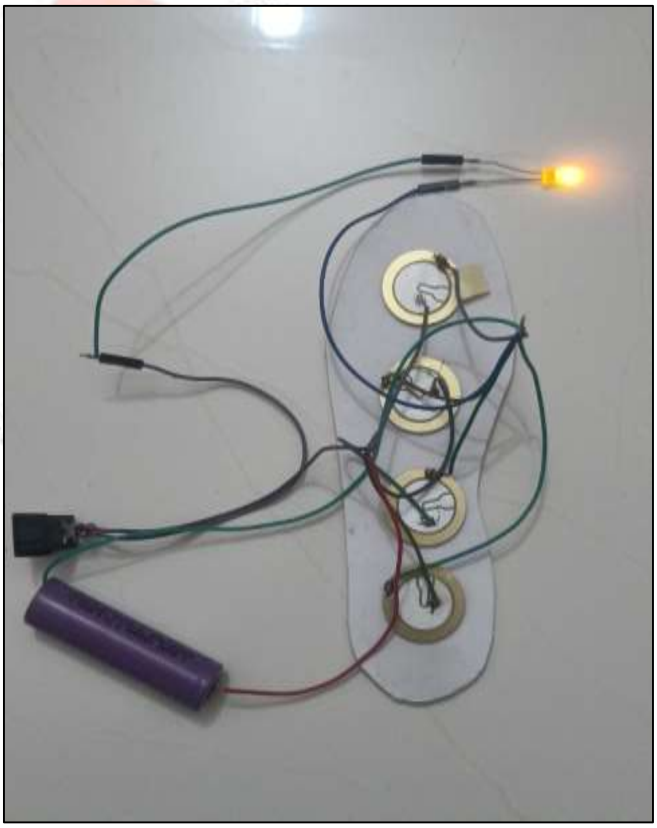

Fig b. Image of prototype with LED

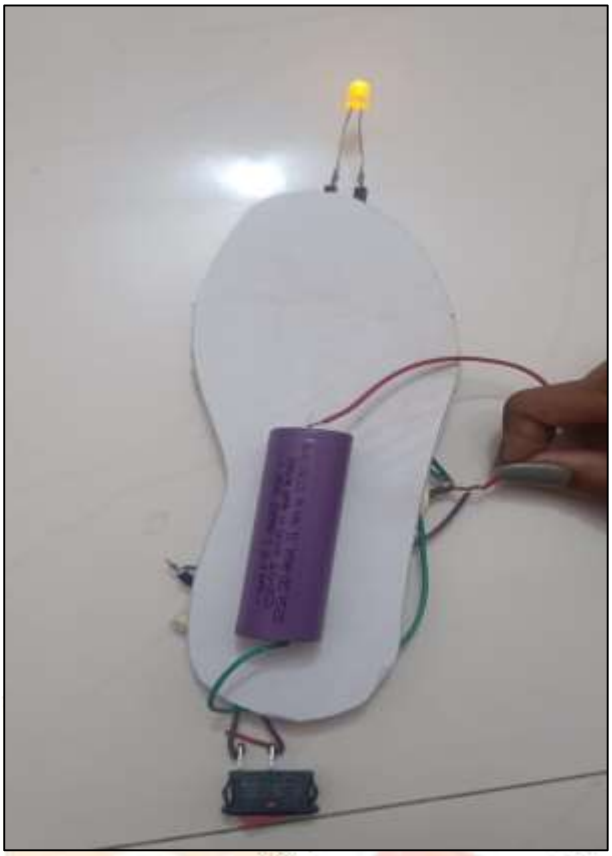

Fig.c. Complete prototype view

VII. CALCULATIONS-

Assumptions:

Acceleration due to Gravity (g): 9.8 m/sec^2
Weight (W): 60 Kg
Displacement (d): 0.012 m
Force Exerted: 1.3 times the weight (1.3W)

The calculations performed in this study provide valuable insight into the potential energy that can be harvested from human motion, specifically through footstep-induced pressure. By determining the energy produced per step, which is calculated by multiplying the force exerted during walking (1.3 times the body weight) by the displacement of the foot, we were able to estimate the energy output for each step. This calculation serves as the foundation for understanding how much electrical energy can be generated through walking, which is essential for evaluating the system's efficiency.

Once the energy per step was established, further calculations were conducted to extrapolate the total energy generated over different numbers of steps. The range from 500 to 10,000 steps was selected to represent a variety of walking scenarios, from short walks to longer distances. These calculations helped quantify the total energy potential, providing a clearer understanding of how much power could realistically be generated in real-world applications. For example, by walking a typical 500 steps or up to 10,000 steps, an individual could contribute a significant amount of energy, which, depending on the system design and the efficiency of the piezoelectric sensors, could power small devices or contribute to energy storage.

In conclusion, these calculations demonstrate the feasibility of harnessing energy from human footsteps, highlighting how relatively simple actions like walking can be leveraged to generate useful electrical power. This approach not only supports the concept of wearable energy-harvesting systems but also showcases the potential of integrating kinetic energy conversion into daily activities. The findings from these calculations emphasize the practical viability of such systems, offering a sustainable and eco-friendly solution to supplement power needs in various applications. Furthermore, these calculations lay the groundwork for future research aimed at optimizing energy conversion efficiency and expanding the range of potential applications for footstep-based energy harvesting systems.

Assumptions			
Acceleration due to gravity	g	9.8	m/sec^2
Weight	W	60	Kg
displacement	d	0.012	m
Force exerted is 1.3 times weight			
1KWh	3.6*10^6	J	
Force	W*g	588	N
Force exerted per step	1.3*Force	764.4	N
Energy produced			
Energy per step	f*d	9.1728	

Results-

The calculated units of energy produced for various numbers of steps are as follows:

For a single Person (in 1 step)			
Units Produced	Total Energy/3.6*10^6	0.000002548	KWh
Sr.No.	Number of steps	units produced	
1	500	0.001274	
2	1000	0.002548	
3	5000	0.01274	
4	8000	0.020384	
5	10000	0.02548	

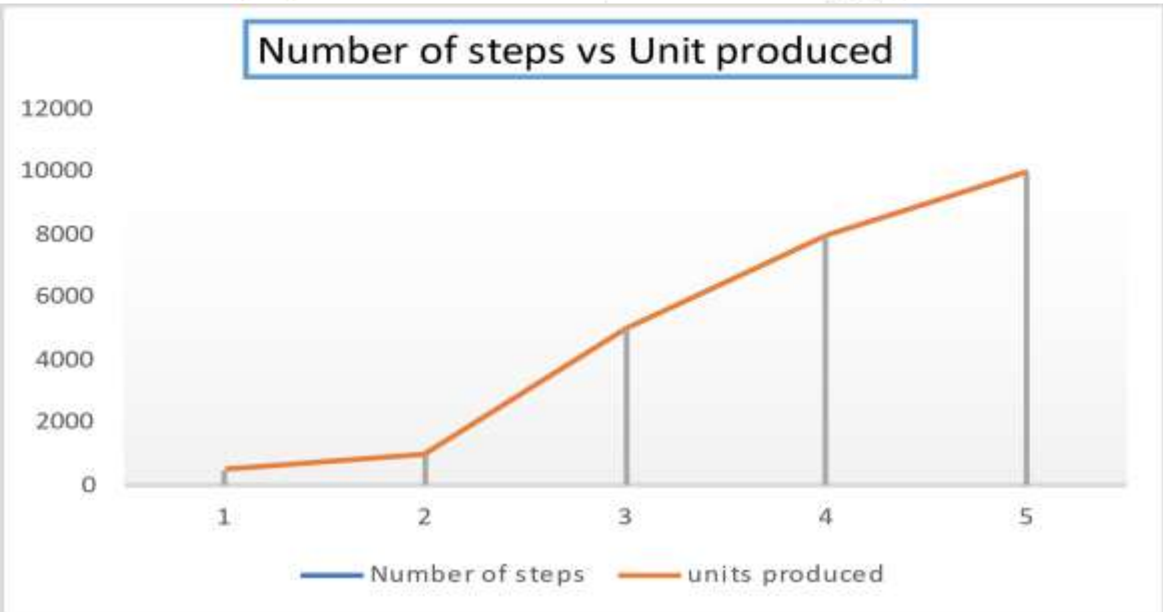

Fig d. No. of units produced VS No. of steps

Additionally, the project involves the calculation of current, voltage, and power produced, providing insights into the efficiency and performance of the system.

VIII. APPLICATIONS-

- Railway Stations: Crowded railway stations experience continuous foot traffic. By embedding piezoelectric sensors in the flooring, the energy generated from footsteps can be captured and converted into electrical power. This power can then be used for lighting, charging stations, or other purposes.

- Bus Stands and Terminals: Similar to railway stations, bus stands and terminals can benefit from footstep power generation. The energy produced by commuters' footsteps can contribute to lighting or other essential services.

- Shopping malls and Theatres: High footfall areas like shopping malls and theatres can utilize piezoelectric flooring to generate electricity. This sustainable energy source can supplement their power needs.

- Installing piezoelectric sensors in sidewalks or pedestrian walkways can generate electricity as people walk. This energy can be stored and used to power streetlights during the night, reducing reliance on conventional grid-based electricity.

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- In rural areas, where access to electricity is limited, footstep power generation can be employed. Farmers walking across fields or pathways can contribute to energy production. This energy can be used for irrigation pumps, lighting, or charging small devices.

- Piezoelectric sensors integrated into emergency exit pathways can provide backup power for emergency lighting. During power outages, these sensors activate and illuminate escape routes.

- Wearable devices, such as shoes with embedded piezoelectric sensors, can capture energy from the wearer's footsteps. This energy can charge small devices like fitness trackers, smartwatches, or GPS trackers.

IX. ADVANTAGES AND DISADVANTAGES-

A. Advantages-

- **Power Generation Through Walking**: One of the key benefits of this energy-harvesting system is its ability to generate power simply through walking. The system captures the kinetic energy produced with each step, converting it into electrical energy. This makes it a practical solution for power generation in everyday activities, without the need for any extra effort.

- **No Fuel Requirement**: Unlike traditional energy generation methods, which depend on external fuel sources, this system operates independently and does not require fuel inputs. It relies on the mechanical energy from walking, making it a sustainable and eco-friendly alternative to conventional power sources.

- **Non-Conventional Power Source**: The system utilizes a non-conventional method of energy generation, moving away from reliance on fossil fuels or electricity from the grid. By harnessing the kinetic energy from human motion, it offers an innovative and renewable solution to power generation.

- **Durability with No Moving Parts**: A major advantage is the absence of moving parts in the system. This design choice minimizes wear and tear, increasing the longevity and reliability of the system.

With fewer components to degrade, the system requires less maintenance and can operate for longer periods without failure.

- **Compact and Highly Sensitive**: The energy-harvesting system is designed to be compact, allowing it to be embedded discreetly into shoes or other wearable items. Despite its small size, the piezoelectric sensors are highly sensitive to pressure and motion, enabling efficient energy conversion without compromising comfort or functionality.

- **Self-Sustaining, No External Power Needed**: This system is entirely self-sustaining as it generates its own power through kinetic energy, without the need for external sources of electricity. This makes it particularly useful in locations where access to traditional power sources is limited, offering a portable, off-the-grid solution for power needs.

B.Disadvantages-

- **Limited to Specific Locations**: The primary limitation of this system is that it is only effective when the user is walking. It cannot generate power when the person is stationary or engaged in non-movement activities. This restricts the applicability of the technology to specific scenarios where walking is involved.

- **High Initial Setup Cost**: While the system provides long-term benefits in terms of energy generation, the initial cost for the setup is relatively high. This includes the cost of integrating piezoelectric sensors, energy storage units, and wiring into the footwear, which can make it an expensive investment, especially for mass production or individual consumers.

- **Temperature Sensitivity**: The performance of piezoelectric materials can be affected by changes in temperature. Extreme temperatures, whether hot or cold, can reduce the efficiency of the sensors, limiting the energy output. This makes the system less reliable in environments with wide temperature fluctuations.

- **Risk of Crystal Damage Due to Overstress**: The piezoelectric crystals used in the system can be prone to cracking if exposed to excessive pressure or stress. Over time, or under high-impact conditions, the crystals may degrade or break, which would compromise the system's ability to generate power. This vulnerability limits the system's durability and requires careful consideration of how the sensors are used.

X. CONCLUSION-

This project successfully demonstrates the viability of generating electricity from human movement through the integration of piezoelectric sensors into footwear. The findings from the experimentation and calculations emphasize the substantial potential for harnessing the kinetic energy produced during everyday activities, such as walking, to generate electrical power. The results indicate that even simple actions, like walking, can be used to contribute to sustainable energy solutions, offering a novel approach to power generation that does not rely on conventional energy sources.

The ability to capture and convert mechanical energy from human motion into electricity represents a significant step forward in the field of energy harvesting. By embedding piezoelectric sensors into shoes, this technology allows for continuous, on-the-go energy generation, providing a practical solution to power small devices or contribute to larger energy systems, especially in areas with limited access to traditional power sources. Additionally, this system could be scaled for use in various applications, from wearable electronics to urban infrastructure, where foot traffic is common.

This approach not only offers an eco-friendly and renewable energy source but also showcases the potential for integrating alternative energy solutions into daily life. As the technology matures, it may open up new opportunities for further research and innovation in the areas of low-power electronics, energy storage, and sustainable energy practices. Future developments could focus on optimizing the efficiency of energy conversion, enhancing the durability of piezoelectric materials, and expanding the practical applications of this energy-harvesting system, ultimately contributing to global efforts to reduce reliance on non-renewable energy sources and improve energy sustainability.

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