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Walking into the Future: Energy Harvesting from Footfall

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Abstract

The rapid depletion of non-renewable energy resources and the rising demand for sustainable alternatives have led to the exploration of innovative energy-harvesting technologies. One such approach is harnessing the untapped mechanical energy produced by human footfalls in crowded public areas. This project presents a novel method of electricity generation using a flywheel-based mechanical system that captures and converts footstep energy into electrical energy. The system is designed to be embedded beneath specially designed floor tiles where the vertical pressure from a human step is transformed into rotational energy. This rotational energy is transferred to a flywheel via a mechanical linkage, such as a spring-loaded cam, gear, or lever mechanism. As the flywheel spins, it stores kinetic energy, which is then used to drive a DC generator or dynamo connected to the same shaft. After passing through a rectifier and voltage regulator, the produced electrical energy can be stored in a bank of capacitors or a rechargeable battery. Low-voltage gadgets like LED lights, fans, or sensors can then be powered by this stored energy. Experimental results demonstrated that a single footstep could produce rotational speeds of 300–500 RPM, depending on the flywheel design and gear ratio, leading to an average electrical output of 3–7 volts. Overall efficiency and energy output increased significantly with the use of a heavier flywheel and an optimized gearing system. This technology is particularly applicable in locations with high foot traffic, such as railway stations, shopping malls, schools, airports, and stadiums, where continuous human movement can be converted into useful energy. Unlike piezoelectric systems, which generate small voltages and are limited by material fatigue, the flywheel mechanism offers better energy storage, mechanical durability, and long-term efficiency. This project proves the potential of converting simple mechanical motion into meaningful electrical power in a sustainable and eco-friendly manner. With further improvements in design, cost optimization, and integration, the flywheel-based energy-harvesting floor system could contribute meaningfully to distributed power generation in smart infrastructure.

Keywords- Footstep energy harvesting, flywheel-based power generation, mechanical energy conversion, sustainable energy systems, human-powered electricity

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INTRODUCTION

In today's world, the rising demand for energy and depletion of conventional fossil fuels have created an urgent need to explore alternative and renewable energy sources. One promising yet underutilized source is the mechanical energy generated by human footfalls, especially in areas with high pedestrian traffic, such as railway stations, schools, malls, and airports. Every footstep carries kinetic energy that usually goes to waste [1–3]. This project aims to harness this energy using a flywheel-based mechanism to generate electricity in a clean and sustainable manner.

The system was designed with a floor tile embedded with a mechanical setup that included springs, levers, gears, and a flywheel. The flywheel rotates when a person steps on the tile because the vertical force is transformed into rotational motion. The flywheel retains kinetic energy and transfers it to a generator to produce electricity. This electricity can then be stored in a battery or used directly to power low-voltage devices, such as LED lights or sensors. This project demonstrates a practical approach to energy harvesting that is not only environmentally friendly but also suitable for integration into modern smart infrastructure [4–6].

This flywheel-based energy-harvesting system offers several advantages over traditional piezoelectric or pressure-based systems. Unlike piezoelectric materials that degrade over time and produce limited voltage, the flywheel mechanism provides a higher energy storage capacity, better durability, and consistent performance. The mechanical components can be easily maintained or replaced, making the system more suitable for long-term use in public installations [7–11]. Moreover, the stored rotational energy in the flywheel allows for a smoother and more continuous power output, even if the footfalls are irregular or infrequent, as shown in Figure 1. By utilizing commonly available materials and a straightforward mechanical design, the system can be fabricated at a relatively low cost, making it feasible for large-scale deployment [12–14].

MAJOR PARTS

Flywheel

The primary energy storage component of the system is a flywheel. It stores rotational kinetic energy when it rotates. The flywheel rotates as a result of the mechanical setup when a person steps on the tile. Additionally, the flywheel lessens the power generation fluctuations caused by differences in footstep force and timing, as shown in Table 1. By smoothing out these uneven inputs, the flywheel guarantees that the generator functions more effectively and with less stress. Furthermore, the flywheel-controlled energy release reduces abrupt torque fluctuations, which can shield the generator and other mechanical parts from deterioration. The flywheel's capacity to store energy increases with its weight and is delivered smoothly to the generator [15].

Spring Mechanism

Spring is placed beneath the foot tiles. When someone steps on the tile, the spring compresses and stores the potential energy. Spring returns to its initial position and releases the stored potential energy in a regulated manner as the foot is raised and the applied force is released. During this release phase, the spring presses against a linked mechanical part, such as a lever or cam mechanism. This contact is essential for transforming the vertical motion of the footstep into a mechanical motion that can be used.

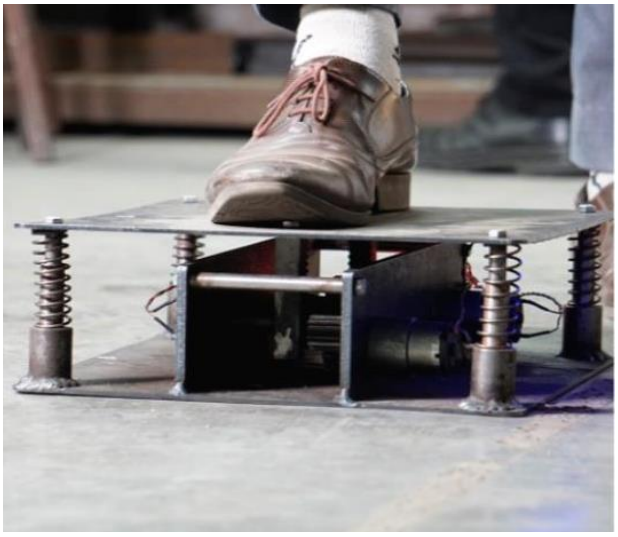

Figure 1. Energy harvesting from footfall.

Table 1. Component specifications.

S.N.	Component	Specs	Purpose
1.	Flywheel	MS, 3–5 kg, Dia-250 mm	KE storage
2.	Spring mechanism	Stiffness 10–15 N/mm,	Restore platform
3.	Lever system	MS,	Transfer foot pressure to rotary motion
4.	DC generator	12 V, 100–200 rpm,	Convert mechanical energy to DC
5.	Rechargeable battery	12 V, 1 Amp	Stores electricity
6.	LED	3 V	Demonstration of output

The linear movement of the spring is converted into rotational or angular motion by the lever or cam system, which is required to power later parts, such as the flywheel [16]. As it releases, it pushes the connected lever or cam mechanism, helping convert the vertical force into motion. The controlled compression and expansion of the spring smooths the uneven characteristics of human footsteps, guaranteeing more uniform energy transfer.

Spring increases system durability by controlling the force supplied to the mechanical linkage to protect downstream components from abrupt shocks or high loads. To maintain the responsiveness of the floor tile while harvesting sufficient energy, the stiffness and substance of the spring are carefully chosen to compromise between the energy storage capacity and user comfort [17].

Lever/Cam System

This mechanism acts as a bridge between the vertical motion of the footstep and the horizontal rotation of the flywheel. The mechanism, which usually consists of a lever, cam, or gear-based arrangement, transforms the linear vertical displacement into a rotating movement after the spring releases its stored energy. This conversion is crucial because the flywheel functions best when driven by a steady, continuous rotational motion.

This mechanism ensures that a large amount of energy from each footstep is transferred to the flywheel with the least amount of loss by precisely designing the mechanical pathway of energy transfer. It takes the energy from the compressed spring and transfers it such that it rotates the flywheel effectively [18].

Shaft and Bearings

The shaft connects the flywheel to the generator. By lowering friction, bearings enable the shaft to rotate smoothly and effectively, which is essential for reliable energy transfer in wind turbines. High-quality bearings are used at critical support areas to guarantee that the shaft rotates smoothly and dependably. The shaft may rotate smoothly with little resistance owing to the bearings, which are crucial for lowering the friction between the moving parts. Bearings help prevent needless energy losses that may otherwise degrade the overall efficiency of the system by reducing mechanical friction. Because the energy input from human footsteps is sporadic and any additional resistance could have a substantial impact on performance, smooth shaft rotation is crucial in this application [19].

DC Generator

The generator is driven by a shaft connected to a spinning flywheel. As the shaft rotates, the generator converts the mechanical energy into direct current (DC) electricity, which can be used or stored for later use. The produced DC electricity can be sent to an energy storage device, such as a rechargeable battery, or directly to low-power electrical loads.

The practicality of the idea is increased by storing the generated energy, which enables the system to build up power over time and make it ready for use when required. LED lights, tiny DC motors, fans, sensors, and USB charging modules can all be powered by the stored energy. The generator and linked electrical components operate safely and dependably owing to the incorporation of appropriate voltage regulation and protection circuits, as shown in Table 2.

Table 2. Performance observation table.

S.N.	Parameter	Measurable value	Remarks
1.	Flywheel speed	200–300 rpm	It depends on the gear ratio and weight
2.	Spring compression per step	30–40 mm	Produce enough force to activate the mechanism
3.	Voltage generated per step	3–7 V	At moderate foot pressure
4.	Time charge 12 V battery	~20–30 mins	Continuous footfall
5.	Energy output/100 steps	~2.5–5 W min	Depending upon generator efficiency
6.	Load powered	3 V LED	10–20 min

Battery (Storage Unit)

The electricity generated by the DC generator was stored in a rechargeable battery. Using proper rectification and regulation circuits, the DC generator transforms the mechanical energy transferred through the flywheel mechanism into electrical energy, which is subsequently conditioned and sent to the battery. This technology prevents losses related to immediate consumption and enables effective long-term utilization by storing harvested energy. Numerous low-power electronic devices, such as LED lighting systems, tiny DC fans, sensors, and USB-based charging connectors for mobile devices, can be powered by the stored electrical energy. The system's usefulness for dispersed power generation in public areas, including train stations, shopping centers, schools, and pedestrian walkways, is demonstrated by these applications. This stored energy can then be used to power small devices, such as LEDs and fans, or charge USB devices later when needed.

METHODOLOGY

The project focuses on converting the mechanical energy of human footfalls into electrical energy using a flywheel-based system. The system was installed beneath specially designed floor tiles. Spring underneath the tile is compressed by the vertical force of footsteps. This spring stores potential energy, which is then released and transferred to a mechanical lever or cam. When the spring is released, its linear motion is transformed into a rotating motion by a mechanical lever or cam-based transmission mechanism. The flywheel is powered by this circular motion, which allows the energy from sporadic footsteps to accumulate and be smoothed. The system can run continuously owing to the increased energy stability and conversion efficiency of the flywheel. Overall, the proposed design presents a feasible method for harnessing human-generated renewable energy for low-power electrical applications in public spaces.

The lever mechanism converts vertical motion into rotational motion, which is used to spin a flywheel. The flywheel acts as an energy storage device, maintaining rotational momentum and smoothing out the irregularities caused by uneven or intermittent footsteps. The rotating flywheel was connected to a shaft supported by ball bearings to minimize friction losses and ensure smooth rotation.

The shaft is connected to a DC generator. The generator is turned by the shaft as the flywheel rotates, transforming mechanical energy into electrical energy. The electricity produced is stored in a 12 V rechargeable battery after passing through a rectifier circuit to change any AC to DC. The system is appropriate for public areas with heavy foot traffic because it can be used to power modest electrical loads such as fans, LED lights, or sensors, as shown in Figure 2.

RESULT AND ANALYSIS

The flywheel-based energy-harvesting system successfully generated electricity through human footfalls. During testing, each step produced a rotational motion in the flywheel, generating approximately 3 V to 7 V depending on the applied force. With continuous stepping (2–3 steps per second), the system was able to charge a 12 V battery within 25–30 min. The system's suitability for practical, low-power applications was demonstrated by the harvested energy's ability to consistently power low-voltage electrical loads, such as LED lighting systems and tiny DC fans.

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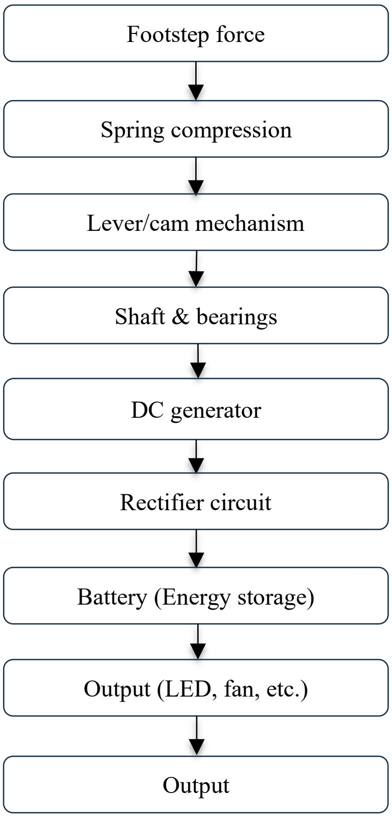

Figure 2. Flow diagram of the footstep-based energy-harvesting system.

According to performance studies, the flywheel is essential for stabilizing energy production because it efficiently stores kinetic energy and gradually releases it, minimizing variations caused by sporadic footfalls. The suggested design demonstrated increased durability and overall efficiency compared to simple piezoelectric energy-harvesting systems. The system is particularly suited for deployment in crowded public areas, such as train stations, retail centers, and pedestrian walkways, because the mechanical components are reliable and long-lasting.

The energy generated was sufficient to power low-voltage devices, such as LED lights and small DC fans. The analysis showed that the flywheel provided a stable energy output owing to its ability to store and release energy smoothly. The overall efficiency was higher than that of basic piezoelectric systems, and the mechanical components were reliable for long-term use in crowded public areas such as stations and malls.

CONCLUSION

The project successfully demonstrates a simple and efficient method of generating electricity using a flywheel mechanism driven by human footsteps. By capturing the mechanical energy created during typical human movement and transforming it into electrical power, the system provides a sustainable and ecologically friendly energy solution for congested public spaces such as train stations, shopping malls, airports, and pedestrian walkways. A flywheel is used in the suggested design to store and control intermittent input energy, increasing conversion efficiency and producing a more steady electrical output. The system uses easily accessible mechanical and electrical parts, requires little upkeep, and produces no direct emissions or noise. The findings support decentralized and sustainable energy generation in high-traffic areas by demonstrating the viability of footstep-based energy harvesting as an additional power source for low-power applications, including lights, sensors, and information displays. It offers a sustainable energy solution for crowded public areas, converting mechanical energy into usable electrical power and promoting renewable energy use with minimal maintenance and low environmental impact.

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