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An Experimental Model and Test of a Novel Sustainable Energy Pad for Bike Lane Applications

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Abstract

Energy harvesting from renewables is an important research topic around the world. Due to the overburning of carbohydrate-based fuels like fossil fuels, the adverse environmental effects, and catastrophes worldwide, researchers are developing technologies for new green energy harvesting systems. In this research, a novel prototype of the Energy Generating Pad (EGP) was designed and tested successfully. The pad was made of a type of thin-film PZT cells. Each cell was connected to an energy collection circuit that connected to the DC power rail (DCPR). The novel EGP technology was developed, fabricated, and tested successfully at the PVAMU's SMART Center for bike lane applications. The EGP is composed of seven layers of compound materials. A 3-feet-long integrated PZT strip of 18 thin-film PZT cells was placed in the middle of the EGP. The prototype of the EGP was tested using an output load of 7.5 kΩ. A bicycle with a rider weighing a total of about 142 pounds served as the mechanical pressure source for the test. The tested PZT cells produced an average of 68 VDC, and the energy of the DCPR was 616.53 mW/s for the rider riding the bike on the EGP.

Introduction

Global energy demand is increasing due to technological advances and consumer patterns that have led to increased energy demand [1-2]. Alternative energy technologies, renewable fuels to produce electricity, represent a global solution because they are clean and renewable. Electricity produced from Piezoelectric energy will be one of the best alternate options everywhere [3-7]. A pad for EGP was designed using a thin-film piezoelectric generator. Piezoelectric generators employ active materials that generate electrical charges when mechanically forced [8-13]. The EGP is developed and tested in the SMART Center Lab at PVAMU. This research work aims to create an alternate power generation source.

Prototyping Model of the EGP

The EGP consists of 3 main parts: top, center, and bottom parts, as shown in figure 1. The bottom part consists of three layers 1, 2, and 3. The bottom part is made of polyester and microfleece fabric coated with acrylic and adhesive mixture fluids. The center part of the EGP constitutes the energy generation source that was made of PZT cells, and they were coated with a special PVC polymer. This part of the EGP circuit had charge collection components and the DCPR. The top part consists of three layers 5, 6, and 7. The top part was made of polyester and micro-fleece fabrics coated with acrylic and adhesive mixture fluids.

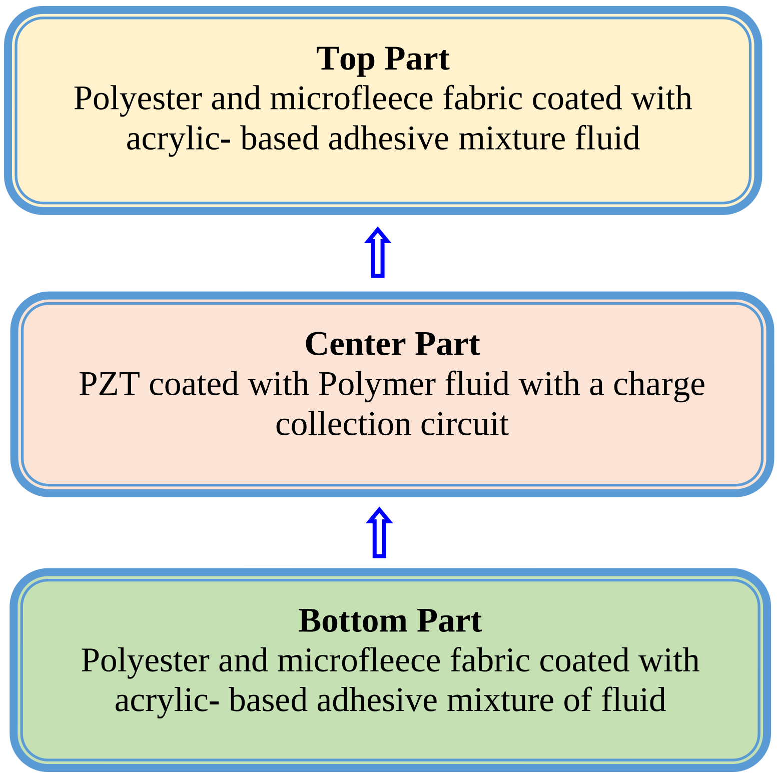

Figure 1: Three Parts of the EGP

Layers 1 and 7 were made of polyester fabric, and they were processed by acrylic-based fluid to make them very hard and solid. Layers 2 and 3 were made of micro-fleece fabrics and were processed by acrylic and adhesive fluids mixtures of a ratio of 3:1 to make them hard and strong. Layer 4 was coated with a special PVC polymer to make PZT cells less brittle. Layers 5 & 6 were made of micro-fleece processed with acrylic and adhesive fluids with a ratio of 2:1 to make the layer rubber-like and very flexible. The flexible layers provided safe placement, protection, and proper adhesion of the energy-generating unit with other laters in the EGP. Properly mixed fluids in layers played a vital role in seamless adhesion. The composition and properties of the seven layers 3-foot long EGP are described in table 1.

Table 1. Layers Compositions & Properties of the Prototype EGP

EGP Parts	Layers	Composition	Fluid Mixtures (ratio)	Properties
Bottom	1	Poly-fabric	Acrylic-based	Hard and unbreakable
	2	Microfleece	Acrylic & adhesive (3:1)	Hard and unbreakable
	3	Microfleece	Acrylic & adhesive (3:1)	Hard
Center	4	Coated PZT	PVC polymer	Hard and less brittle
Top	5	Microfleece	Acrylic & adhesive (2:1)	Rubber-like flexible
	6	Microfleece	Acrylic & adhesive (2:1)	Rubber-like flexible
	7	Poly-fabric	Acrylic-based	Hard and unbreakable

One of the challenges in this technology was energy collection and utilization of power from the PZT cells in the EGP. An energy collection and storage system is developed to overcome these challenges. When a bike rider was running on the EGP, the PZT cells inside of the EGP instantly produced acyclic high peak AC voltage. This AC signal of energy was converted to a DC voltage source by a charge collection circuit. The DCPR helped to store the energy into the battery to utilize the maximum energy. Figure 2 represents the processing of energy collection and storage steps in the EGP power system.

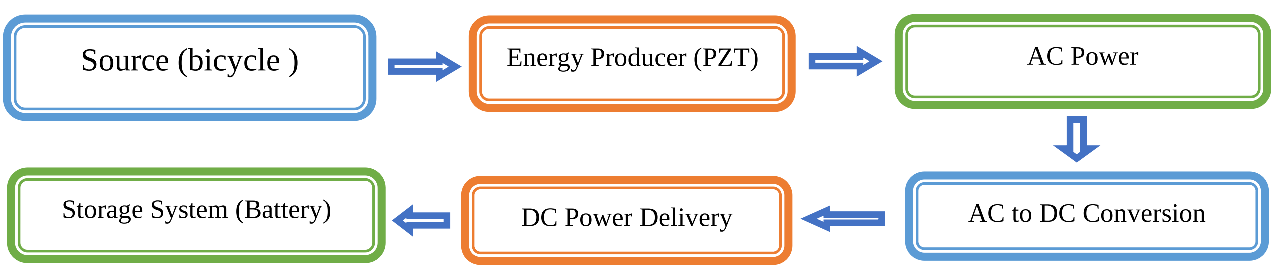

Figure 2: The Processing of Energy Collection and Storage Steps in the EGP Power System.

Experimental Results

A seven-layered 3-feet long EGP power system was developed successfully, as shown in figure 3. A bike rider repeatedly ran on the EGP to determine the pad's quality and reliability. A 7.5 kΩ load was used for the test. The average voltage of the three-feet EGP produced 68 VDC by the pressure from a rider of 142 lbs (including the bike weight), and the pad's power was 661.53 mW/s from each PZT strip. The results of these tests are shown in table 2.

Table 2. The experimental outcome on the Bike lane EGP

Items	Specifications & Results
EGP Length	3 Feet
Output Voltage	68 VDC average at 5 mph
EGP Layers	7
Tested load	7.5 kΩ
Total weight of the bike with rider	142 pounds
Speed of the running bike	2-7 mph
Power of each DCPR strip	66.53 mW/s

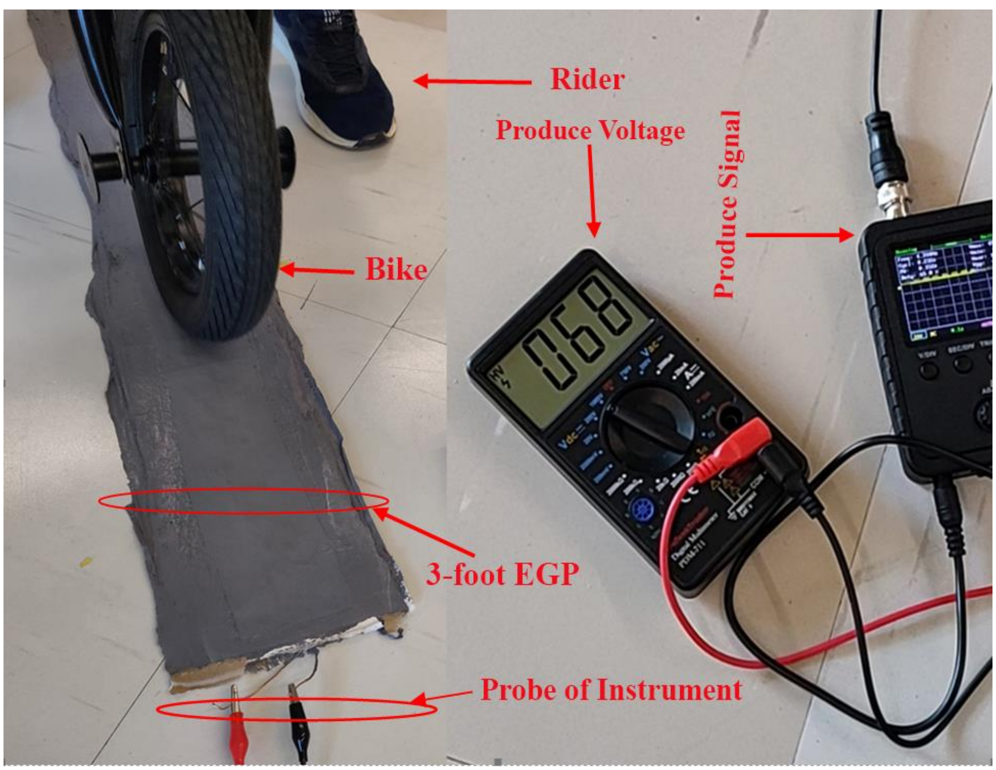

Figure 3: A Three-Feet EGP is tested in the SMART Lab.

It was found that when the bike was running at the speed of 2 mph (2.93 fps), the output voltage of the pad was 28 VDC. In contrast, when the speed was 5 mph (7.33 fps) the voltage was 68 VDC. When the speed was 7 mph (10.27 fps), the voltage increased to approximately 85 VDC, as shown in figure 4. The test data are shown in table 3. Based on this, the relationship between the speed and the output voltage was established.

The general solution of impact produced by speed and the output voltage from the EGP by running the bike in the lab was found as:

$$y = 0.0257x^3 - 1.0833x^2 + 18.008x - 15.952 \quad (1)$$

where, y = the rail voltage (VDC)
x = the speed of the bike (fps).

The EGP would be placed outdoors on the actual bike lane. Based on the general solution, the average speed of 15 mph (22 fps) would produce 130 VDC. As a result, more power can be generated at higher bike speeds. So, significant improvement of energy generation is achievable by an improved EGP will be the next step in this project. However, further research may improve energy production up to 20% by changing layer thickness, fabric quality, PZT types, and the proportions of the adhesive mixtures. Currently, all materials in the EGP layers are not 100% hydrophobic. The EGP gathered some moisture in lab experiments after two days when immersed in water, and it produced less energy than expected.

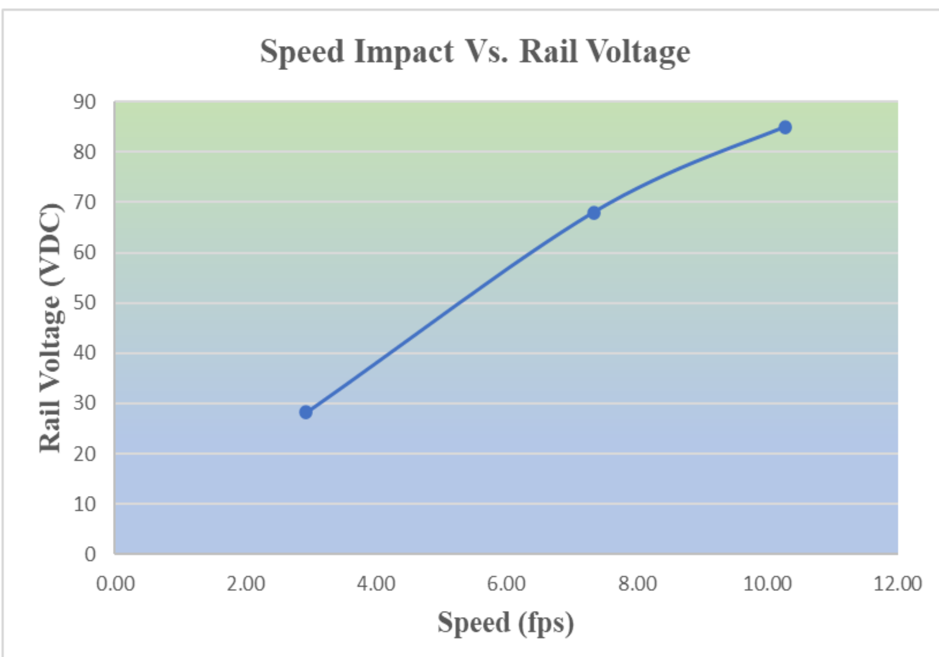

Figure 4: The Relationship Between Speed and the Voltage Generation.

Table 3. Testing Results on the Running Bike Under the EGP.

Speed		Rail Voltage
fps	**mph**	
2.93	2	28.2
7.33	5	68
10.27	7	85

Conclusions

In this work, a novel design of EGP for bike lanes has been developed in the laboratory at the SMART Center at Prairie View A&M University. In this research, various experiments were conducted to find proper materials, fluids, and mixtures for fabricating the EGP. Through these experiments, a type of polyester and micro-fleece fabrics were identified. These fabrics were coated with acrylic and adhesive mixtures of fluids in the prototype of the EGP. The EGP successfully produced energy from the three-feet EGP which was about 661.53 mW/s per PZT cell strip in the EGP by the running bike at 5 mph. Finally, it could be one of the sources to generate alternative electricity for society. Currently, This sustainable EGP can be used easily in many parts of the world where it rarely rains because this EGP is not 100% hydrophobic. So, the EGP can easily be implemented in dry areas and desert countries, including Saudi Arabia, UAE, and Egypt.

Future Work

A new mixture of fluids will need to be developed to make the EGP layers 100% hydrophobic. After that, the newly developed EGP can be deployed in any part of the world. A 10-feet EGP will be placed on an outdoor bike lane that will be used to test the impact of the bike's speed above 15 mph. The customized electronics system for the charge collection process for the battery and the power supply management system will be developed. Additionally, an algorithm-encoded program will be developed for furnishing the hardware and software solution using microcontrollers. The 10-feet EGP will be used to determine the longevity, quality, power generation characteristics, sustainability, and mechanical strength.

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