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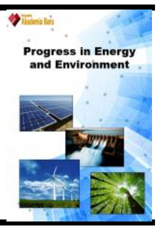

Energy Harvesting of Daily Human Life Activities using a Self-Made Piezoelectric System

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ABSTRACT

An energy harvesting device is a new way to supply power to micro electronic devices when a conventional energy sources does not exist by converting the mechanical energy into electrical energy. The mechanical energy that have been chosen is vibration from human activities where it can be easily harvested from human foot. Piezoelectric energy harvester has been fabricated and installed in a street shoe to convert the vibration to electrical energy. The piezoelectric material that have been selected is Polyvinylidene Fluoride Polymer Film (PVDF) because of the flexibility and the durability of the material among the others materials. Most of the previous researchers focus on harvesting vibration energy on heel. However, there are other parts of foot that can generate higher energy than the heel. Therefore, the purpose of this study is to find out the part of foot that can harvest the highest energy and investigate the human activities that can generate high electric energy. The parts of foot are heel, ball of foot and thumb toe and the human activities are walking at speeds of 2 km/h, 3 km/h and 4 km/h, and running at speeds of 5 km/h, 7 km/h and 9 km/h. From the results obtained, the location of the harvester that produced optimum peak-to-peak voltage (V_{pp}) is at the ball of foot with 1.9 V at 9 km/h speed. The higher the speed and stress, the higher the electrical energy that the energy harvester can produced.

1. Introduction

Energy harvesting device is a system that has been designed to seize small amount of the surrounding energy and convert it into applicable electrical energy [1]. These devices have their own benefits such as portable, wireless, eco-friendly, cost effective and usually in small-scale [2]. Nowadays, the reduction of gadget size and its applications in diverse field has been increasingly developed, i.e. wireless sensor. Therefore, the harvesting energy concept has been given a great attention in technological community to continuously reducing the power usage of microelectronic devices [3]. Examples of ambient energy that can be harnessed are natural light, thermal electromagnetic and mechanical sources [4]. One of the most popular energies that has been harvested

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is mechanical vibration energy. This source of vibration energy is ubiquitous and can be harnessed continuously anytime without limitation of space [1]. A rigid body also can produce a low-level mechanical vibration that induce by unbalance mass or wear and tear of a material in all dynamical systems [5] such as vehicles, human motion and machinery. Besides that, human body can produce energy that can be harvested. A convertible and continuous source of energy can adequately harvest from human waking. The heel strike and swing from the foot movement could accelerate and excite large forces [6]. Therefore, energy harvesting from foot motion is conducted in the present study. This study is implementing a small level for power generation using a shoe .The vibration sources from human activities that can be easily harvested are on their foot. Most of the researchers only focus on putting the harvester device at the heel. However, based on Emanuele et al. [4], there are other zones that produce greater pressure. There is no research on the other parts of foot besides the heel as the location of the transducer in harvesting energy. This study is to prove that there are other parts of the foot that can excite high energy to the energy harvester. The objective of this study is to identify the maximum electrical power that can be harvested based on different daily human activities and the maximum electrical power that can be harvested based on different part of foot of the harvesting device.

2. Methodology

This harvesting system is focused on three places of the highest pressure on foot which is on the toe thumb, ball of foot and heel strike [4]. The daily human activities that have been chosen is walking and running because these activities are the general activities that human do in their daily life.

The experiment is conducted in UTM KL gymnastic, and a treadmill is required in the experiment. The piezoelectric energy harvesting system is applied on the shoes. The electrical energy that is exerted by the energy harvester is measured by using oscilloscope. The schematic diagram of the experiment set up is shown in Fig. 1 and the location of the energy harvester that is located on the foot is shown in Fig. 2. The frequency of each of the human activities is determined by using an accelerometer. The accelerometer is attached to the respondent's leg by using masking tape and connected to the Simcenter Scadas Mobile to gain the data. The overall setup is shown in Fig. 3.

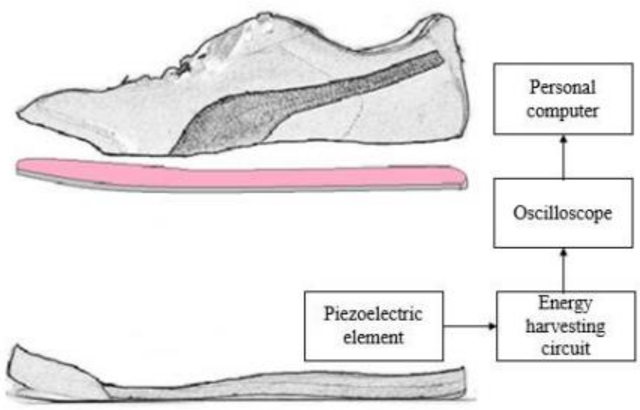

Fig. 1. The schematic diagram of the design and setup of experiment

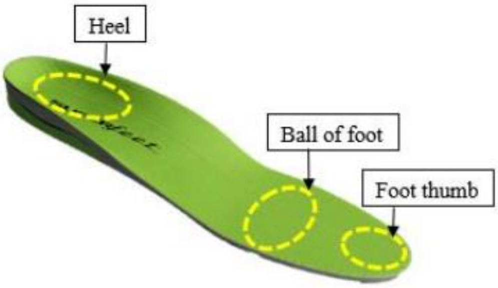

Fig. 2. The location of the energy harvester that is being located on the foot

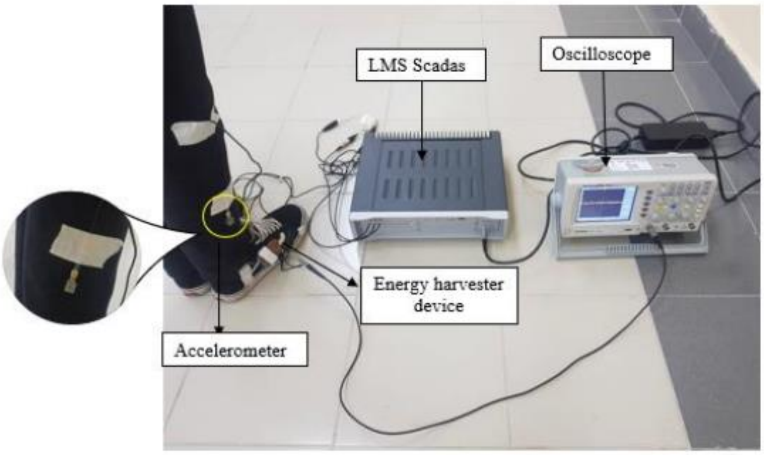

Fig. 3. The Experimental Setup

The variables of the experiment are shown in Table 1. The speed of the activities is controlled by using treadmill. The piezoelectric material that have been selected is Polyvinylidene Fluoride Polymer Film (PVDF) because of the flexibility and the durability of the material among the others material.

Table 1 Experiment variable

Human Activities	Speed (km/h)
Walking	2, 3, 4
Running	5, 7, 9

3. Results and Discussion

An oscilloscope is used to find the voltage gain from the experiment. All of the data needs to be extracted from the oscilloscope by using USB Flash Drive. Fig. 4 is the graph of the voltage gain of the energy harvester on the ball of foot at 9 km/h speed. Since the data shown is not constant, root mean square voltage (V_{rms}) is used to find the relevant peak-to-peak voltage (V_{pp}). The V_{rms} is determined by using Octave Software. Then, equation 1 is used to find the V_{pp}.

$$V_{pp} = V_{rms} \times 2\sqrt{2} \tag{1}$$

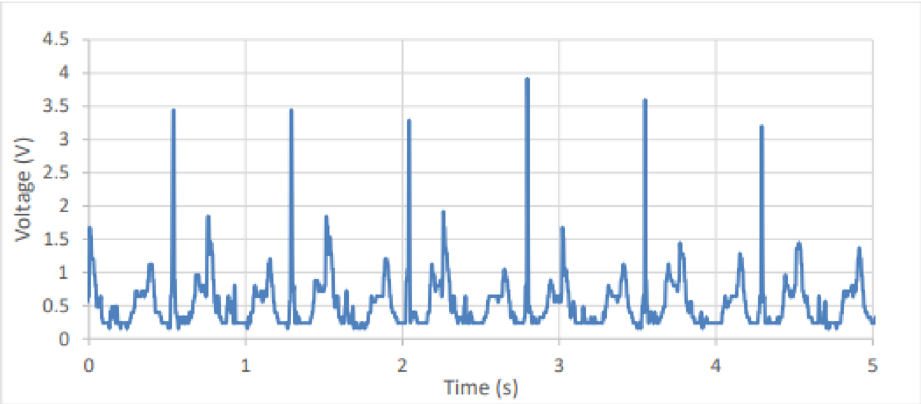

Fig. 4. Voltage gain (V) on ball of foot at 9 km/h

Fig. 5 shows the voltage that is harvested on the foot of various parts. The data trend is found to be a clearly upward and is very similar among the three locations. The higher the speed, the higher the voltage peak-to-peak (V_{pp}). The result shows that ball of foot harvests higher peak-to-peak voltage compare to heel and foot thumb. Among the speeds, the highest achievable voltage is 1.92 V at speed of 9 km/h. When the respondent is running, the foot is stepping on the energy harvesting device faster than walking and a considerable force of 220% of body weight has been discharged [4]. Therefore, the more stress is applied to the energy harvesting device and produced high electricity. The foot thumb and heel harvest lesser energy than ball of foot because both of the parts has lesser stress than ball of foot. This result is relevant since previous researchers have found that maximum strain was obtained around ball of foot [7]. Table 2 shows the value of voltage peak-to-peak gain at various part of foot and speeds. The differences between the lowest V_{pp} and the highest V_{pp} value at speed of 9 km/h is 27.76 %. Heel generates 8.02 % higher energy than foot thumb and ball of foot generates 21.46 % higher than heel.

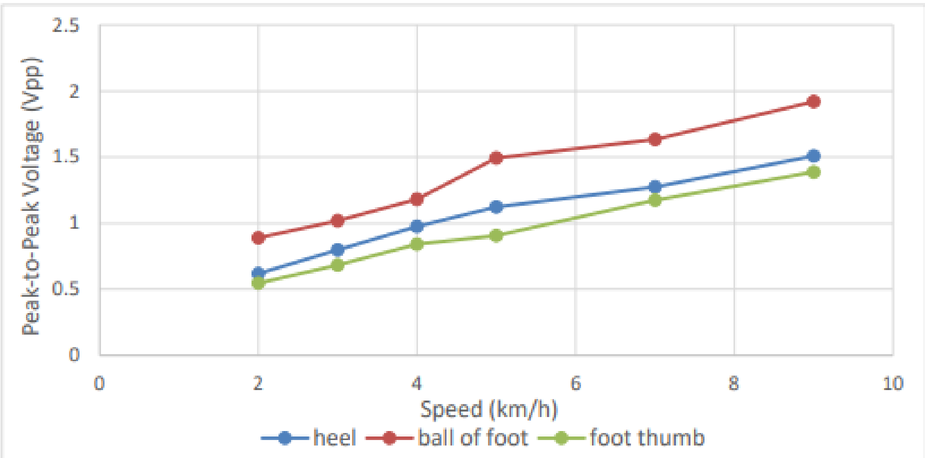

Fig. 5. Voltage that is harvested on the foot

Table 2 Voltage peak-to-peak gain at hell, ball of foot and foot thumb due to different speed

Speed (km/h)	Voltage Peak-to-peak (V)		
	Heel	Ball of foot	Foot thumb
2	0.618	0.889	0.546
3	0.797	1.019	0.682
4	0.975	1.180	0.841
5	1.122	1.493	0.906
7	1.274	1.634	1.175
9	1.508	1.920	1.387

4. Conclusion

In this research, an energy harvesting device has been fabricated by using Polyvinylidene Fluoride Polymer Film (PVDF) as the piezoelectricity transducer that fit into the sole of the shoes. An experimental study on the performance of the harvesting device has been performed at three locations of the foot which are ball of foot, heel and foot thumb to analyse the optimum amount of energy that can be harvested. Besides, different daily human activities which are walking and running at constant speeds are also investigated. To ensure the energy harvester that has been fabricated is functional, an oscilloscope is used to measure the output voltage. Then, the experiments have been conducted at the Universiti Teknologi Malaysia Kuala Lumpur Gymnasium. A treadmill is used to control the speed of the runner. The raw data from the oscilloscope was extracted using USB Flash Drive and was analysed using Microsoft Excel and Octave Software.

The objectives of this research have been successfully achieved. From the experiment, PVDF harvester has successfully generated electrical energy from human daily activities which are walking and running. The optimum peak-to-peak voltage is affected by the speed of daily human activities and the locations of the foot. The results show that the higher the speed of daily human activities, the higher the peak-to-peak voltage output. In short, the optimum harvested electrical power in the daily human activities is found during running at 9 km/h which is 1.92 V. The highest speed produces the highest peak-to-peak voltage. The location of the energy harvester that harvested the optimum electrical power is at the ball of foot because the pressure applied on the ball of foot is the highest compare to the others.

References

[1] A. Keshmiri, X. Deng, N. Wu, New energy harvester with embedded piezoelectric stacks, Compos. Part B Eng. 163 (2019) 303–313. doi:10.1016/j.compositesb.2018.11.028.

[2] K.V. Selvan, M.S. Mohamed Ali, Micro-scale energy harvesting devices: Review of methodological performances in the last decade, Renew. Sustain. Energy Rev. 54 (2016) 1035–1047. doi:10.1016/j.rser.2015.10.046.

[3] E. Dallago, M. Marchesi, G. Venchi, Analytical model of a vibrating electromagnetic harvester considering nonlinear effects, IEEE Trans. Power Electron. 25 (2010) 1989–1997. doi:10.1109/TPEL.2010.2044893.

[4] A.M. Emanuele Frontoni, Energy harvesting applied to smart shoes, J. Mech. Eng. Technol. 9 (2018) 412–421.

[5] M. Shishesaz, M.M. Shirbani, H.M. Sedighi, A. Hajnayeb, Design and analytical modeling of magneto-electro-mechanical characteristics of a novel magneto-electro-elastic vibration-based energy harvesting system, J. Sound Vib. 425 (2018) 149–169. doi:10.1016/j.jsv.2018.03.030.

[6] F. Qian, T.B. Xu, L. Zuo, Design, optimization, modeling and testing of a piezoelectric footwear energy harvester, Energy Convers. Manag. 171 (2018) 1352–1364. doi:10.1016/j.enconman.2018.06.069.

[7] R. Kakihara, K. Kariya, Y. Matsushita, T. Yoshimura, N. Fujimura, Investigation of piezoelectric energy harvesting from human walking, J. Phys. Conf. Ser. 1052 (2018). doi:10.1088/1742-6596/1052/1/012113.