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Preliminary study-design of a piezoelectric floor energy harvester

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ABSTRACT

A piezoelectric-based electrical energy harvesting device has been designed using a cantilever method that originates from mechanical pressure from humans climbing stairs. The method in this research uses an experimental method where there are variations in the load given by humans of 55 Kg, 65 Kg, and 75 Kg to provide force on an energy harvester that has 4 piezoelectric circuits installed, 38 of which are installed in series and parallel. piezoelectric, where the four circuits have a number of piezoelectrics of 10, 8, 10 and 8 piezoelectrics on each side. The resulting voltage will later be rectified using a rectifier bridge until it will be temporarily stored in the capacitor. The voltage is rectified using a rectifier bridge and stored in capacitors. The test was carried out in conditions where the respondent was walking leisurely and running. The results obtained without a rectifier circuit is 0.87 V, 1.06 V, 1.08 V. For a parallel circuit it is 0.78 V, 0.87 V, 0.96 V. In the rectifier circuit, it is obtained for a series circuit of 0.53 V, 0.66 V, 0.75 V. Electric current 0.01 mA, 0.03, 0.06 mA for parallel circuits 0.46 V, 0.78 V, 1.07 V and electric current 0.05 mA, 0.06 mA, 0.019 mA.

ABSTRAK

Telah dirancang suatu alat pemanen energi listrik berbasis piezoelektrik dengan metode kantilever yang bersumber dari tekananan mekanis dari manusia yang sedang menaiki tangga. Metode pada penelitian ini menggunakan metode eksperimen dimana terdapat variasi pembebanan yang diberikan oleh manusia sebesar 55 Kg, 65 Kg, dan 75 Kg untuk memberikan gaya pada suatu alat pemanen energi yang telah terpasang 4 buah rangkaian piezoelektrik, dimana dipasang secara seri dan paralel berjumlah 38 buah piezoelektrik, dimana pada keempat rangkaian tersebut memiliki jumlah piezoelektrik sebanyak 10, 8, 10 dan 8 buah piezoelektrik pada masing-masing sisinya. Hasil tegangan nantinya akan di searahkan menggunakan jembatan penyearah hingga nantinya akan disimpan sementara pada kapasitor. Tegangan disearahkan menggunakan jembatan penyearah dan disimpan kapasitor. Pengujian dilakukan pada kondisi responden berjalan santai dan berlari. Hasil pengujian tanpa rangkaian penyearah didapatkan tegangan listrik 0,87 V, 1,06 V, 1,08 V. Untuk rangkaian paralel 0,78 V, 0,87 V, 0,96 V. Pada rangkaian penyearah didapat untuk rangkaian seri sebesar 0,53 V, 0,66 V, 0,75 V. Arus listrik 0,01 mA, 0,03, 0,06 mA untuk rangkaian paralel 0,46 V, 0,78 V, 1,07 V dan arus listrik 0,05 mA, 0,06 mA, 0,02 mA.

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1 Introduction

In line with renewable energy's aim, it acts as an energy reserve that can reach areas that conventional electrical energy generators cannot. In the future, it can also become the primary source of electrical energy generation. Several studies have presented optimizing several minor components to support increased efficiency in a renewable energy generator [1]. Piezoelectricity is a material that has very unique properties. When piezoelectricity is subjected to vibration or mechanical pressure, polarization will occur in the piezoelectric charge, which is called piezoelectricity. Energy harvesting from piezoelectricity has been carried out by experts [2]. Researched the design of an energy harvesting prototype using piezoelectricity as a power generator using a method of making a stamping medium on the floor, resulting in a maximum power output of 3.48 W after being passed through a full wave rectifier. For the same number of steps on the piezoelectric array, the increase in charging voltage of a 150 mAH Li-Po battery is smaller than the 250 mAH type [3]. One way of converting waste energy into electrical energy is to use footsteps. Researchers became interested in using wasted or unused energy [4] [5], which is often forgotten and not utilized optimally. Another researcher researched an energy harvesting system on the floor using the BQ25570 module in the piezoelectric energy harvesting application. The results of the tests carried out were produced when the weight was 42 kg was 1.3 mW, 52 kg was 2.2 mW, 67 kg was 4.7 mW, 70 kg was 1.06 mW, and 82 kg is 1.7 mW [6].

Another research using LTC3588-1 is on the Design and Implementation of Piezoelectric Carpets for Energy Harvesting [7]. Using piezoelectric audio which is arranged with layers of rubber and resin to strengthen the structure so that it is not easily damaged. As an energy harvester, an LTC3588 and a capacitor with a capacity of 100 uF are used and monitored with a Human Machine Interface (HMI) module. Piezoelectrics are arranged in the form of a matrix measuring 16x10 pieces and connected in parallel. From the tests carried out, the external capacitor voltage was 1.1 V in the 5 minute walking and jumping test and the energy was equivalent to 60.5 μJoules. In this research, the LTC3588-1 functions as a transmitter and amplifier of piezoelectric current which is then distributed to an external capacitor [8].

Another researcher has compared of piezoelectric charging of capacitors with batteries. This research method is tapping a 2.7 cm diameter piezoelectric using a finger with a frequency of 30 bpm, 60 bpm, 90 bpm, 120 bpm, 150 bpm, and 180 bpm to charge a 47 uF capacitor. observed every 10 seconds for 90 seconds [9]. Taps of 30, 60, 90, 120, 150, and 180 bpm produce final capacitor voltages of 0.57 V, 0.88 V, 0.98 V, 1.33 V, 1.38 V, and 1.4 V, respectively. Several methods are widely used to harvest electrical energy from human body movements, such as body heat, hands, body movements, or footsteps [10] [11] [12].

This research aims to design and manufacture a prototype device for an electrical energy harvesting floor module. Several piezoelectric material are placed on the floor module with a cantilever beam system. Cantilever beam, the most widely used mechanical structure, is trapped with the forced and redundant vibration while working which is the hot spot for both academia and industry [13].This research was carried out by creating a series of piezoelectric experiments, in the form of series, parallel and combined arrangements, which will then be studied for the voltage and electric current produced [14]. Then for the arrangement of laying the piezoelectric material using the cantilever method where a load is applied at the end. With this method, it is hoped that the electrical energy produced by the floor module will reach optimum.

2 Research Methodology

2.1 Method

In this study of preliminary design, an experimental research method are used, which is carried out by observing the test results on electrical energy generating devices derived from piezoelectricity, where the source of electrical energy comes from vibrations where the vibrations is obtained from mechanical pressure which is forwarded to move the cantilevers so that there is mechanical pressure on piezoelectricity. The results of this test will later be validated with the Piezoelectric Constitutive Equation [15]. This research also uses two research variables, namely the independent variable and the dependent variable. The independent variables in this study are energy harvesting devices, load weight, electrical circuit systems. While the dependent variable in this study is the amount of voltage output produced.

2.2 Scheme of Research

This research was conducted by making a piezoelectric-based electrical energy harvester with a cantilever method, including the manufacturing process and material selection. An electronic circuit, in the form of a piezoelectric experiment circuit where the piezoelectric circuit is arranged in series and parallel which will then be taken the largest voltage and current. This energy harvesting device channels mechanical energy from human loading which will be channeled through a cantilever at the end of which will be given a load in the form of nuts and bolts. The provision of pressure variations will later be given by human loads with variable masses of 55 kg, 65 kg, and 75 kg, respectively, with a number of presses of 10 presses. After the piezoelectric is arranged, the next step is to change the output voltage from the piezoelectric in the form of AC voltage (alternating current), into DC voltage. Therefore, an AC to DC rectifier circuit is required. Then the current will enter the capacitors in order to produce stable electricity.

Because in the previous process electrical energy still has a small voltage and current and is not yet stable to be used in a device, the voltage and electric current generated will be accommodated through storage in the form of a capacitors or batteries, then before it is accommodated, a diode is used which functions as a voltage block before going to the battery. Only later will it be used as a channeling medium to be used for its utilization to turn on the LED / Utility lights.

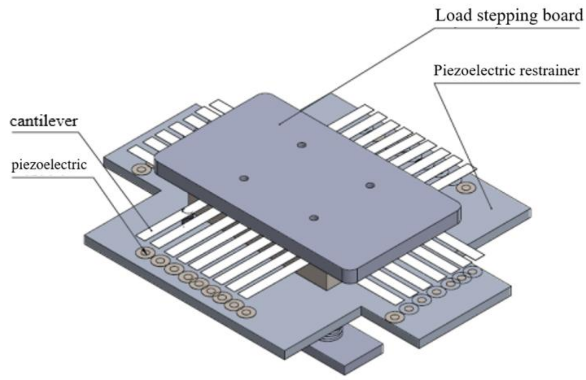

Figure 1. Initial Design of Energy Harvester

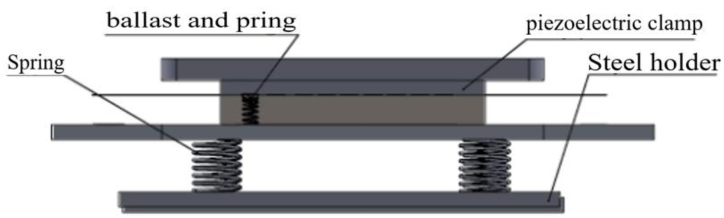

Figure 2. Front Face of The Harverster Initial Design

2.3 Research Procedure

2.3.1 Retrieval Concept Data

The data collection process is divided into two types, namely with a multimeter measuring instrument and Labjack T7-Pro, as for the explanation as follows.

a. Voltage and Current Testing Using a Multimeter
   Data collection using a multimeter is used to determine the amount of voltage and current in the energy harvesting device. The type of circuit that will be calculated is a series and a parallel circuit. For each circuit will be measured using a multimeter on variations without rectifiers and capacitors.
b. Voltage and Current Testing Using Labjack T7-Pro
   Data collection using Labjack T7-Pro is used on energy harvesting devices as a measuring tool for voltage values in series and parallel circuits. The voltage measured is on variations using rectifiers.

2.3.2 Experiment Procedure

a. Experimental procedure using a multimeter
   1. Prepare an energy harvester with series and parallel circuits.
   2. Prepare load variations of 55, 65, and 75 kg.
   3. Adjust the circuit variation on the piezoelectric which is without rectifier and capacitor.
   4. Connect the multimeter to the piezoelectric circuit.
   5. Give loading ranging from 55, 65, and 75 kg for 10 stomps.
   6. Calculate the voltage and current when given the load.
   7. Perform steps 3 through 6 for each of the other circuits.
b. Experimental procedure using Labjack T7-Pro
   1. Prepare the energy harvesting device with series and parallel circuits.
   2. Prepare load variations of 55, 65, and 75 Kg.
   3. Adjust the piezoelectric circuit variation using a rectifier.
   4. Connect the Voltage Sensor to the Labjack T7-Pro and the piezoelectric circuit.
   5. Perform module settings on the Labjack T7-Pro on the Laptop.
   6. Give loading starting from 55, 65, and 75 Kg for 10 stomps.
   7. Record data for one loading process using Labjack T7-Pro when the energy harvester is given loading.
   8. Do step 7 up to 10 times for each load.
   9. Perform steps 3 through 8 for each - every other circuit.

3 Results and Discussions

3.1 Retrieval Results

3.1.1 Device Testing on Series Circuit

The test results on the series circuit on each side, as for each side has a different number of piezoelectrics, where side A is 10, B is 8, C is 10 and D is 8, obtained as in the table below.

Table 1. Output Results on Series Circuit Without Rectifier

Weight (kg)	Step	Volt (V_{AC})			
		Circuit			
		A	B	C	D
55	10	0.477	1.163	0.862	1.013
65	10	1.152	1.067	0.917	1.107
75	10	1.059	1.072	1.122	1.065

Table 2. Output Results on Series Circuit with Rectifier

Weigh (kg)t	Circuit	Voltage (V_{DC})	Current (mA)	Power (mW)
55	A	0.313	0.009	0.003
	B	0.384	0.011	0.004
	C	0.331	0.007	0.002
	D	1,117	0.015	0.017
65	A	0.582	0.011	0.006
	B	0.466	0.011	0.005
	C	0.548	0.010	0.006
	D	1,083	0.022	0.024
75	A	0.630	0.014	0.009
	B	0.660	0.014	0.009
	C	0.708	0.008	0.006
	D	1,036	0.031	0.032

Table 3. Output Results in Series Circuit with Capacitors

Weight (kg)	Circuit	Voltage (VDC)	Current (mA)	Power (mW)
55	A	1.809	0.006	0.011
	B	2.925	0.011	0.032
	C	3.223	0.012	0.039
	D	2.327	0.012	0.028
65	A	1.872	0.008	0.015
	B	5.177	0.011	0.057
	C	1.604	0.013	0.021
	D	3.710	0.015	0.056
75	A	3.578	0.014	0.050
	B	4.307	0.021	0.090
	C	1.417	0.017	0.024
	D	3.107	0.015	0.047

3.1.2 Device Testing on Paralel Circuit

The test results on the parallel circuit on each side are obtained as in the table below.

Table 4. Output Results on Parallel Circuit without Rectifier

Weight (kg)	Step	Voltage (V_{AC})			
		Circuit			
		A	B	C	D
55	10	0.741	0.376	1.149	0.888
65	10	0.867	0.412	1.268	0.938
75	10	0.938	0.585	1.431	0.908

Table 5. Output Results on Parallel Circuit with Rectifier

Weight (kg)	Circuit	Voltage (V_{DC})	Current (mA)	Power (mW)
55	A	0.655	0.002	0.001
	B	0.584	0.008	0.004
	C	0.382	0.004	0.002
	D	0.235	0.005	0.001
65	A	0.961	0.006	0.007
	B	1.321	0.012	0.015
	C	0.521	0.005	0.002
	D	0.321	0.003	0.001
75	A	1.198	0.008	0.009
	B	0.797	0.020	0.016
	C	1.111	0.006	0.007
	D	1.183	0.010	0.012

Table 6. Output Results on Parallel Circuit with Capacitors

Weight (kg)	Circuit	Voltage (VDC)	Current (mA)	Power (mW)
55	A	0.746	0.004	0.003
	B	1.316	0.008	0.010
	C	0.473	0.008	0.004
	D	0.525	0.002	0.001
65	A	1.005	0.007	0.007
	B	1.312	0.009	0.012
	C	0.282	0.007	0.002
	D	0.708	0.009	0.007
75	A	1.741	0.012	0.021
	B	1.022	0.008	0.009
	C	0.450	0.009	0.004
	D	0.944	0.020	0.018

3.2 Comparative Analysis of Data

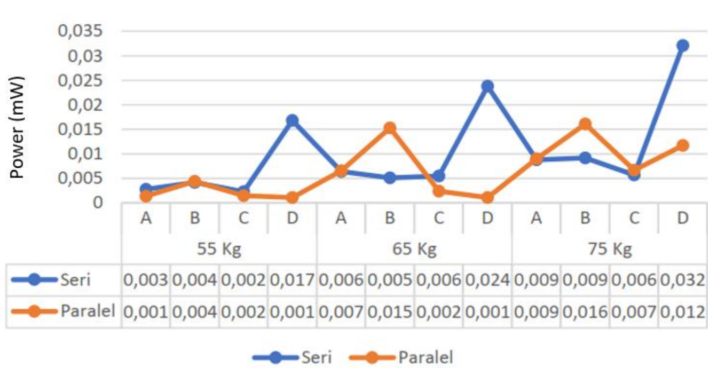

Figure 3. Series and Parallel Rectifier Power Chart

In the graph of the comparison of series and parallel rectifier power with a weight of 55, 65, and 75 Kg obtained in parallel circuits for the highest average value of power obtained in circuit B with a weight of 75 Kg while the value is 0.016 mW. Then the smallest average power value is in circuit D at 55 and 65 Kg loads, which is 0.001 mW. The average power results on each load look fluctuating both 55, 65, and 75 Kg loads. It is also seen that the power value at 55 Kg load is smaller than the other loads. At 75 Kg load has the largest average power compared to other loads.

Then in the series circuit, the highest average power is obtained in circuit D at a load of 75 kg, with a value of 0.032 mW. For the smallest average power is at a load of 55 Kg in circuit C of 0.002 mW. In this series of graph movements tend to fluctuate in each load. There are 3 circuits namely A, B, and C have the smallest average power of each load compared to the average power in circuit D. The amount of power is strongly influenced by the value of the voltage and current produced.

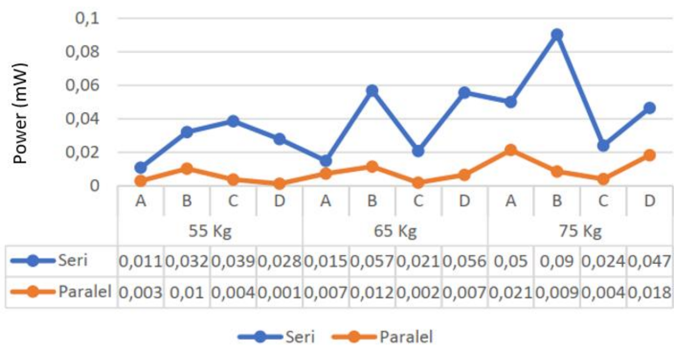

Figure 4. Series and Parallel Capacitor Power Comparison Chart

The next graph shows the comparison of series and parallel power with capacitors at a weight of 55, 65, and 75 kg. The highest value in the average power generated by the parallel circuit is located in circuit A at a load of 75 kg with a value of 0.05 mW. As for the smallest value, it is located in circuit D at a load of 55 kg with a value of 0.001 mW. In this parallel circuit, the movement of the graph direction is quite fluctuating, characterized by the ups and downs of the resulting power. Both at a weight of 55, 65, and 75 Kg both have fluctuating graphs.

Furthermore, in the series circuit, the highest average power value is obtained in circuit B at a load of 75 kg with a value of 0.09 mW. For the average value - the smallest power is in circuit A at a load of 55 Kg with a value of 0.011 mW. In the average graph results on this power the tendency of the movement of the graph is very fluctuative. The difference in average power results is very striking at loads of 65 and 75 Kg. As for the 55 Kg load, it is relatively quite the same.

The amount of electrical energy generated by this piezoelectric-based energy harvester is greatly influenced by the amount of pressure and the frequency of the pressure given. The selection of methods and variables will be very good in product development for the future. The other influential thing is the selection of the type and type of piezoelectricity, the difference in material and type can be used to make the latest variations.

4 Conclusions

The conclusions contained in this research are:

1. The use of piezoelectricity as a micro power plant can be done, but the efficiency of the electric power produced is still lacking so it needs to be optimized and developed again on the methods, types of materials, utilities and applications.
2. The results of the design of piezoelectric-based energy harvesting devices using cantilevers are considered good enough to produce the number of frequencies of emphasis on piezoelectrics,
3. The results of the calculation and test analysis show that the voltage value produced is still not too large, but it can still be utilized for low power usage utilities. Or it can be stored in storage if you want to use it. These results are more or less also influenced by the force distributed on the cantilever decreasing due to energy losses in each spring so that it affects the calculation and testing.
4. The factors that affect the size of the energy value produced in piezoelectric-based electrical energy harvesting devices with this cantilever method are the unevenness of the average between cantilever loads that knock on piezoelectrics, reduced and different mechanical pressures on each load due to the force distribution process, the type of circuit used, and the condition of the electronic connection.
5. Obtained from the calculation results, from each loading the voltage value is 7.762 mV, 11.103 mV, and 17.55 mV respectively. Then for the test results without rectifiers that are averaged in the series circuit at loads of 55, 65, and 75 Kg.

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