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Production of Electrical Energy through Thermo-Electric Effect

Rabiu T.O[1*], Yekinni A.A[1], Lamidi S.B[1]
[1]*Department of Mechanical Engineering, Lagos State Polytechnic, Ikorodu*
**Correspondence Author: Rabiu T.O*

ABSTRACT: *This work focused primarily on the utilization of wasted heat from automobiles, industrial plants, generators and several other sources hence, thermoelectric principles was employed in the conversion of wasted heat into useful electricity. Thermoelectric generators (TEGs) are devices that employ Seebeck effect in thermopile to convert temperature gradient induced by waste heat into electrical power. The design of the TEG system is composed of three main parts, namely: the cooling system, the charcoal heating system and the thermoelectric module used to generate the electricity. The heating source is provided by burning charcoal while the cooling is provided by water running from an opened water tap. The analysis of results revealed that the higher the heat, the higher the voltage generated as the output and there is an apparent increase in the power and current of the system. The greater the heating and cooling effect, the greater the amount of direct current (DC) that the Seebeck modules will generate.*
Keywords: *Thermoelectric, Seebeck effect, electrical power, charcoal heating, cooling, heating*

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I. INTRODUCTION

Development of alternative efficient and clean energy generation systems as well as recovery of waste into electrical power is motivated by the increase in greenhouse gases emissions in the atmosphere due to burning of fossil fuels [1]. Several attempts have been made in the past, and researches are still ongoing to reduce the greenhouse emissions and reduce dependence on fossil fuels through design of numerous power-generation systems, such as solar panels, wind turbines, and geothermal power plants, which utilize renewable energies [2]. Power generation systems that use fossil fuels often require high maintenance and are also expensive when compared to thermoelectric generator devices (TEGs). According to Basel and Wael, [3], thermoelectric generator device (TEG) is described as a device that directly converts heat into electricity. Such device could consist of thermopiles, that is, a set of thermocouples built by legs of p-type and n-type semiconductors, which are connected electrically connected in series and thermally in parallel. In other to obtain reasonable generation regime from the process, thermocouples built by legs of p- and n-type semiconductors are required to be sandwiched between two ceramic plates, and then held at two different temperatures [4]. As a result of temperature gradient induced between top and bottom ceramic plates, voltage is originated on TEG poles due to Seebeck effect in thermocouples built by legs of p- and n-type semiconductors.

Lidorenko and Terekov [5], affirmed that it is cost-effective to employing waste heat as heat source for TEGs because waste heat being free of charge, readily and abundantly available. However, through heat dissipation, about 70% of the world energy production is known to be wasted into atmosphere. This scenario has contributed immensely to global warming [6]. Therefore, the utilization of waste heat by converting it into electricity through TEGs will not only contribute to energy savings but will also result in preservation of the environment. It is also possible for thermoelectric device to operate in reverse mode as thermoelectric cooler (TEC) to produce reverse temperature gradient between top and bottom ceramic plates due to Peltier effect, if electrical bias is applied [7]. Therefore, the condition that will initiate flow of electrical current for subsequent production of temperature difference between the top and bottom plates for TEM to act as thermoelectric cooler or otherwise will depend on operation mode and application of bias voltage to thermoelectric module (TEM). The position of TEM in temperature gradient results in the occurrence of voltage on TEM poles such that TEM acts as heat pump with the function of thermoelectric generator (TEG) [8]. Thermoelectric devices possess numerous advantages when compared to other power-generation systems. TEGs are known as attractive power-generation systems, because they are noiseless solid state devices without moving parts, environmental and ecofriendly, scalable from small to giant heat sources, and highly reliable. They also have prolonged lifetime with ability to utilize low-grade thermal energy to generate electrical energy [9].

A thermoelectric generator is a solid state device that converts heat flux (temperature difference) directly into electrical energy through the phenomenon called the Seebeck effect (a form of thermoelectric effect). Thermoelectric generators function like heat engines, but are less bulky and have no moving parts [8]. Thermoelectric generators are applicable in power plants for the purpose of converting waste heat into additional electrical power and in automobile as automotive thermoelectric generators (ATGs) to increase fuel efficiency. Further application is in radioisotope thermoelectric generators which could be used in space probes, with the same mechanism but using radioisotopes to generate the required heat difference [10].

Thermo-electric materials which will generate power directly from heat by converting temperature differences into electric voltage must have both high electrical conductivity (σ) and low thermal conductivity (κ) to be good thermoelectric materials. Such that, having low thermal conductivity ensures that when one side is made hot, the other side remains cold and ensures generation of large voltage while in a temperature gradient. The measure of the magnitude of electrons flow in response to a temperature difference across such material is given by the Seebeck coefficient [11]. The efficiency of any given material to produce a thermoelectric power is also governed by its "figure of merit"
$zT = S_2 \sigma T/\kappa$.

The most three popularly known semiconductors having both low thermal conductivity and high power factor are bismuth telluride (Bi_2Te_3), lead telluride (PbTe), and silicon germanium (SiGe) [12]. These materials have very rare elements which make them very expensive compounds.

The use of Nano-Technology has made it possible to lower the thermal conductivity of semiconductors without affecting their high electrical properties. This can be made possible by creating nano-scale features such as particles, wires or interfaces in bulk semiconductor materials. However, the manufacturing processes of Nano-materials still have a lot of challenges [13].

In conclusion, a thermoelectric circuit composed of materials of different See beck coefficient (p-doped and n-doped semiconductors), configured as a thermoelectric generator. This work is aimed at taking advantage of Seebeck effect to locally produce electrical energy through thermo-electric effect with modification to the existing designs.

II. MATERIALS AND METHODS

This study was conducted in the thermodynamics workshop of Mechanical Engineering, Lagos State Polytechnic Ikorodu, Lagos State, Nigeria.
The construction of this thermoelectric generator consists of three major components which all made up this thermoelectric generator;

i. Thermo-electric materials
ii. Heating and Cooling Source
iii. The fabricated components parts.

The heating source of the TEG is provided by the use of a charcoal. The charcoal has a chamber which is located at the back of the fabricated body parts (plate 1). The charcoal is loaded by pulling out the tray from the chamber and filled it with the charcoal, then a little amount of fuel is sprinkled on the charcoal and then ignited. After this process, the charcoal is placed where there is enough ventilation or the charcoal is blown with hand fan just to ignite the charcoal to burns well. After the charcoal is burning, the tray is then fixed back to the chamber. The greater the heating and cooling effect, the greater the amount of DC that the see-beck modules will generate.
generate.

Plate 1: Heating chamber

2.1 Cooling Source.

The cooling source is provided by water which is been cooled in the process. During this process, the pumping machine is switched on which then in turns pumps the water from the reservoir in which it was fixed with containing cooled water. The water is pumped up and then, the water tap is opened to allow the free flow of the water in the other reservoir located at the top into the main reservoir used for cooling fixed with the see-beck modules. This process is needed to regulate the temperature of the cold side of the see-beck module.

2.2 The Fabricated Components Parts

In this process of fabrication, angled iron was used to make the frames while galvanized flat metal sheet was used to cover up the body of the frame (plates 2 and 3). Wooden plank was used to lay up the steps of the inside of the frame which then help support the load placed inside which made up the body of the whole system.

Plate 2: Body Frame coupling

Plate 3: Body Frame Welding process.

proportionality factor (α) called the Seebeck coefficient, or $V = \alpha\Delta T$. The value for α is dependent on the types of material at the junction.

2.3 The Thermoelectric Module

The thermoelectric module is the electricity generator in the system. It works only in the principle of heating and cooling (Temperature Difference) supplied to its surface at booth opposite side. The greater the heating effect supplied to the surface of the plate and the effective cooling of the opposite surface which will in turn allow the flow of electron within the thermoelectric elements inside the module.

2.4 Voltmeter Reading

If the connection of the module is in series, it increases the voltage and keeps the current constant. But if arranged in parallel, the current increases and the voltage remains constant which also requires a booster to boost or step-up the voltage generating from the TEG modules so as to meet the required voltage needed by the charge controller or regulator to charge up the battery.

2.5 The 12v Dc Water Pump

The dc water pump is also employed to the system in order to help pumped and regulate the temperature of the cooling effect through the continuous flow of water from the main reservoir tank located at the top of the main components to the reservoir cooling the module and the pump reservoir which receives the water directly from the cooling reservoir cooling the modules surface.

2.6 The Cooling Effect Of Water And Heating Effect Of The Burning Charcoal

The cooling effect and heating effect of the burning charcoal were both supplied to the system at the same time. The is done at the same time because as the hot side of the module is introduced to heating effect of the burning charcoal, the heat escaped to the cold side which then requires the cooling effect to maintain the surface temperature of the cold side due to the heating effect which is regulated before the modules then in turns begins to generate electricity.

2.7 The Heat Sink

The Thermo-electric generator (TEG) generating output power is direct current (DC) which have been possible because of the effect from both cooling and heating provided to the system. The power generated from our TEG system is limited due to the few models which are not readily available and we were able to use the little power generated which was being connected to a booster module which step-up the volts generated and its outputs is connected to the charge regulator which in-turns charge up the battery and stored the energy in the 12 volt 18 Amp battery through charging. The use of a 500 Watt inverter with the charge regulator was also introduced to the system. The main function of the charge controller or regulator is to use the little energy generated by the TEG modules to charge up the battery and the 500w inverter along with the 12v battery when connected to the charge regulator, the inverter will convert the Direct Current (DC) stored in the battery as input and convert it into Alternating Current (AC) as output for use by the electrical appliance (load) introduced to use up the power generated.

The design have been modulated into a simple design in which were fabricated using angle iron with flat galvanized sheet, two water reservoirs, a 12v dc pump, heat sink, water hose, wood plank, heating source (which is filled with charcoal).in the inverter battery charger regulator hand pumping machine is put inside the box to stop the water tank is on the top of the box, the heating and cooling source is located at the back of the box and some switching power source is located at the back of the box. The whole system is kick-started by firstly, feeling of the eating sauce with charcoal and lightning off and lightning it up to generate it. The empty water tank is then also filled up with water and DPC pumping machine is kick-started and the power generator begins to the 18 and cooling supplied to dissipate moved at the same time.

III. RESULTS AND DISCUSSION

At the end of the experiment, the following results were obtained.

3.1 Human Body Temperature as the Heat Source

The first test was conducted using the human body temperature as heat source at ambient room temperature and an aluminum heat sink as its cold side. This test generates the results shown in table 1 and graph plotted in figure 1.

Table 1: Human Body (Left Palm) as Heat Source.

Voltage Output (mv)	Current Output (mA)	Power = V*I (μ W)	Inference
45	7.2	360	Body heat can generate uW range of power
50	6.5	292.5	
60	8.4	504	
51.7	7.37	385.5	

3.2 The Use of Charcoal as the Heat Source

The second test was conducted using Charcoal as a heat source. The outcome of the results is then observed and recorded on the table 2 given below. Figure 2 shows the graph.

Table 2: The use of charcoal as the heat source.

Voltage Output (V)	Current Output (A)	Power = VxI (W)	Inference
6	1.2	3.8	Generated energy from temperature difference of heating effect of the burning charcoal and cooling effect of the water to the TEG modules has the potentials to generate 2.5W
7.3	1.4	3.95	
9.5	1.8	4.2	
14.5	2.2	5.9	

3.3 The Measured Output from the Thermoelectric Generator.

After the testing with the SP1848-27145, proving that the thermoelectric module can act as a generator, we then proceed to the development, fabrication and the assembly of other components needed in developing the device.

The table 3 below shows the measured outputs of the device. Energy generated is regulated with the three available pieces of thermoelectric module.

Table 3: Measured output from the thermoelectric generator.

Voltage Output (V)	Current Output (A)	Power = V*I (W)	Inference
0.96	0.69	0.66	Generated energy from temperature difference from the cooling effect of water and the heating effect of the burning charcoal
1.28	1.01	1.29	
1.98	1.71	0.27	

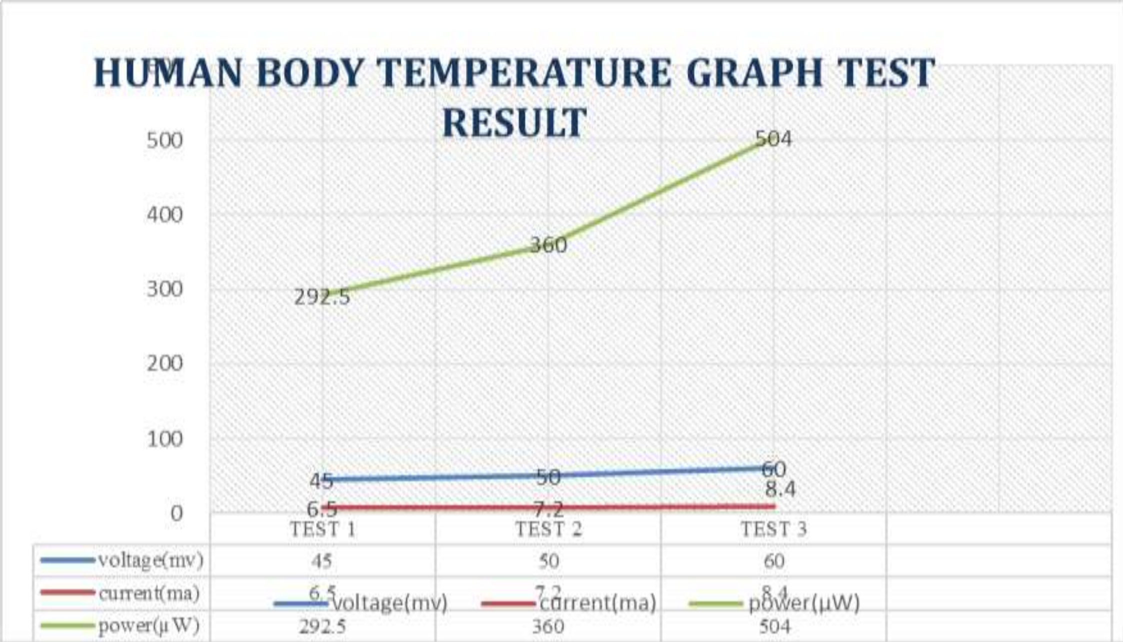

Figure 1: Graph of Human Body (Left Palm) as Heat Source.

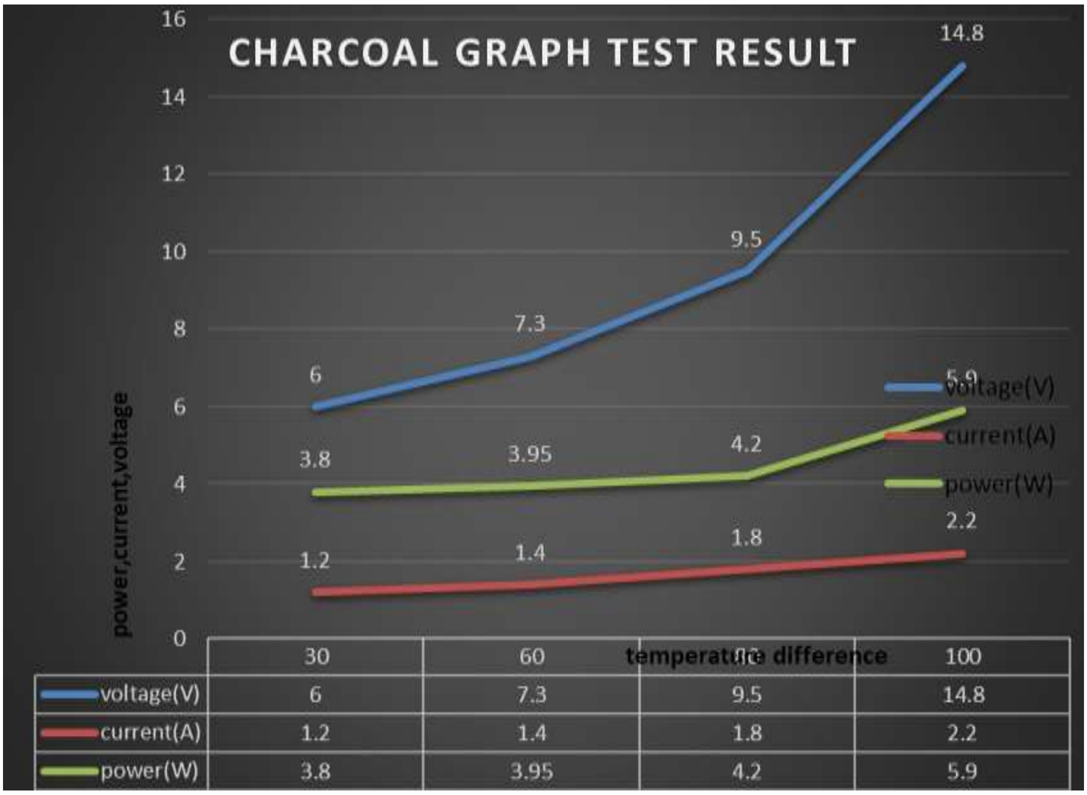

Figure 2: Graph of charcoal as the heat source

IV. RESULTS AND DISCUSSIONS

The analysis discussed and prescribed in this experimental research introduced the results obtained from figures 1 and 2 above as a confirmation of the theoretical concept of the measured voltage, currents and power generated for each of the experimental results.

We kept the temperature on the hot side at about 200°C by using a digital thermostat and used the tap water as the source of cooling on the cold side with a temperature of about 20°C. The temperature was measured using two micro-thermocouples with very thin tips. The temperature on the hot side of the modules was stabilized at about 180°C and that on the cold side at about 40°C. The increase in the temperature on the cold side from 20 to 40°C was because of the heat conduction from the hot side through the TEG modules. The temperature difference was stabilized at around 140°C. The results illustrate that the test system for thermoelectric power generation was stable.

The output of each see-beck is dependent of the performance of the cold side and the hot side working conditions whose efficiency will always determine the final output.

V. CONCLUSIONS

It can be concluded from the results that:

- Due to slight increase in temperature of the body, there is a corresponding increase power, that is, increase in voltage and current. This is as a result of the little amount of heat generated from the palm of the human body.
- The higher the heat, the higher the voltage generated as the output. There is also an apparent corresponding increase in the power and current of the system.

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