Thermoelectric Power Generation Using Bismuth-Tin module

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Abstract

In recent years, as fossil fuel reserves going deplete and increasing environmental issues of emissions, in particular global warming and has resulted in extensive research into new technologies of generating electrical power. Thermoelectric power generators have emerged as an alternative green technology due to their distinct advantages. Thermoelectric power generation is one of the direct energy conversion techniques which convert waste heat energy into useful electrical energy. In the present work thermoelectric power generator is fabricated and tested for different temperature gradients for getting the voltage output accordingly.

Keywords: Thermo electric power generation, waste heat recovery, thermo electric materials, alternative green technology

1. Introduction

Fossil fuels (coal, fuel oil and natural gas) still meet the major part of our energy demand and are getting fast depleted. Moreover, there are serious pollution hazards like greenhouse effect and global warming which occur due to fossil fuel burning. The use of nuclear power too has its own problems and nuclear fusion yet to be realized in practice. We have been forced to for non-conventional power generation system so as to reduce fossil fuel consumption by increasing the conversion efficiency from fuel to electricity. A substantial fuel economy can be achieved by converting heat energy directly to electricity by eliminating the link process of producing mechanical energy via steam (Rankine cycle). Major direct energy-conversion devices are magneto thermodynamic, thermionic, thermoelectric generators and fuel cells. A thermoelectric power generator is a solid state device that provides direct energy conversion from heat energy due to a temperature gradient into electrical energy based on “Seebeck effect”.

The basic concept of thermoelectric power generation is discussed and recent patents of thermoelectric power generation with their relevant applications to waste-heat energy are

reviewed [1]. A Thermoelectric power generator is a semiconductor device that provides direct energy conversion from heat energy into electrical energy based on “Seebeck effect”. The thermoelectric power cycle, with heat carriers serving as the working fluid, follows the fundamental laws of thermodynamics and intimately resembles the power cycle of a conventional heat engine [2]. Waste heat recovery systems for power generation are gaining interest among the marine transport sector as a solution to accomplish the upcoming more restrictive regulations on emissions, and to reduce the total fuel consumption. In their paper Maria E. Mondejar et.al evaluated how a waste heat recovery system based on a regenerative organic Rankine cycle (RORC) could improve the performance of a passenger vessel [3-5].

2. Experimental Setup

First we have purchased a Peltier element that is used for cooling applications. Peltier element works on the principle of “Peltier Effect”. Peltier effect defined as whenever a Dc source is connected to a Peltier element having two dissimilar semiconductors in it a temperature difference was created in it that can be used in cooling applications. The vice-versa of this Peltier effect can be used for our experiment. In our experiment we have used “Seebeck effect” to produce a Dc voltage. Whenever temperature difference is maintained between the two plates of a Peltier element then a Dc voltage will be produced by it. The voltage is developed because of the Seebeck effect causing electrons to flow from N region to P region of the Semiconductor material.

2.1 Specification of Thermoelectric Module

- Ceramic Material: Alumina (Al_2O_3)
- Solder Construction: 138ºC, Bismuth Tin (BiSn)
- TEC1-12706
- The 127 couples, 40 mm × 40 mm size single module which is made of our high performance in got to achieve superior cooling performance and 70℃ or larger delta T max, is designed for superior cooling and heating applications.

A. Solder

T100: BiSn (Melting Point=138ºC)

T200: CuSn (Melting Point= 227 °C)

B. Sealant

NS: No sealing (Standard)

SS: Silicone sealant

EPS: Epoxy sealant

Customer specify sealing

C. Ceramics

Alumina (Al_2O_3, white 96%)(AlO)

Aluminium Nitride (AlN)

D. Ceramics Surface Options

Blank ceramics (not metalized)

Metalized (Copper-Nickel plating)

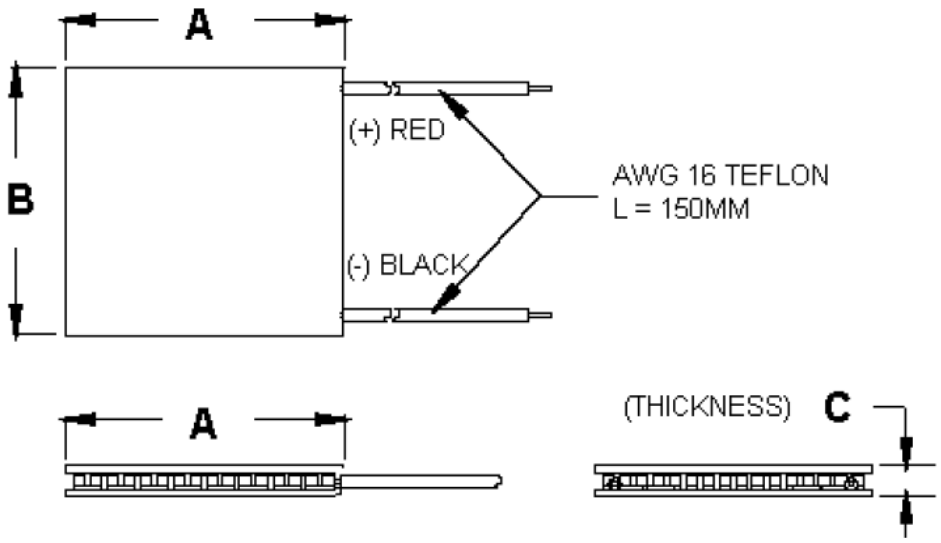

Fig.1.Geometry of thermo electric module

2.2 Construction of Thermoelectric Generator

There are three main steps to construct a thermo electric generator, which are essential to produce a DC voltage and safe operation of the thermoelectric generator [6]. Since there is no rotating parts present in this machine there is no need to provide any gears and lubrication. The energy conversion takes place directly from heat energy to electrical energy. So there are less conversion losses compared to any energy conversion machine. We have constructed this

thermoelectric generator to utilize the heat energy at maximum extent. The main steps involved in constructing thermoelectric generator are

1. Providing a metal bed

2. Heating Techniques

3. Cooling Techniques

1. Providing a metal bed

The Peltier element we have purchased can be treated with direct contact of heat, but we have constructed a metal bed to maximize the heat transfer rate and heat utilizing capacity of the material. The metal bed we have constructed given a chance for better cooling option. The material we have used to construct the metal bed was Aluminium, it is a good conductor of heat and can be sustainable at higher levels of temperature. We have taken a long Aluminium sheet and cut it into the small pieces with the size of Peltier element.

A short Aluminium piece is taken and cut it into just bigger than the element. Now we have made holes on the corners of each bigger piece using a metal drill. We have taken nut and bolts to construct a metal bed with these aluminium sheets. In the bigger pieces with holes, we have placed screws and tighten them with using bolts. Now the metal bed is ready. We have taken 25mm screws for metal bed to stand properly. Now we have taken our element inside the metal bed and rested it on one side of the metal bed. We have place small pieces of aluminium one after other, and up to the top metal piece. This system helps in the cooling purpose and to provide efficient heat transfer throughout the element.

2. Heating Techniques

We have done this project to utilize the waste heat energy from any heat source, but taking our limitations into the account we have used a candle heat to supply the heat to the element. We have taken a candle and cut it into the small pieces with the length of height of the metal bed and placed under the metal bed. This is the heating source we have used to create temperature difference between the two sides of the element.

3. Cooling Techniques

We have to cool the element from one side in order to maintain the temperature difference between the sides of the element and to heat transfer from one side of the plate to the other side of the plate.

The technique we have used here to cool the element is Evaporative cooling. It include a water tub and cotton wicks. As we have already constructed a metal bed to place the element in it and we have

placed all the short aluminium pieces in it. Now we have placed wet cotton wicks in between each and every metal piece. First we have to place a wet cotton wick between the colder side of the element and first metal piece and then after the same technique will be continued. Now the other ends of the cotton wicks place in the water bath to get the water when the water in the wicks evaporated. Now we have constructed a complete thermoelectric generator with heating and cooling systems. The other ends of the cotton wicks place in the water bath to get the water when the water in the wicks evaporated. Now we have constructed a complete thermoelectric generator with heating and cooling systems.

3.Working

Whenever we have supplied heat to the lower end of the metal bed using candle, aluminium sheet gets heated up and it transfers heat to the adjacent Peltier element, in which it has p and n regions. So the electrons in the n-region get energized by the heat energy end travel from n-region to p-region, which allows the current to flow in the circuit. We have connected a DC motor with rating of 6 V. Whenever the electron movement takes place the motor starts to rotate. This total system works based on the temperature difference only, so we have to ensure that other side of the system is gets cooled by the cooling system provided by us. When the heat transfer takes place between the Peltier element and the metal piece on the cooling side, the which is in between them gets heated up and water in the wick evaporated, So the wick has a capability of absorbing water again into it. By this system we can maintain the temperature difference between the two sides of the system.

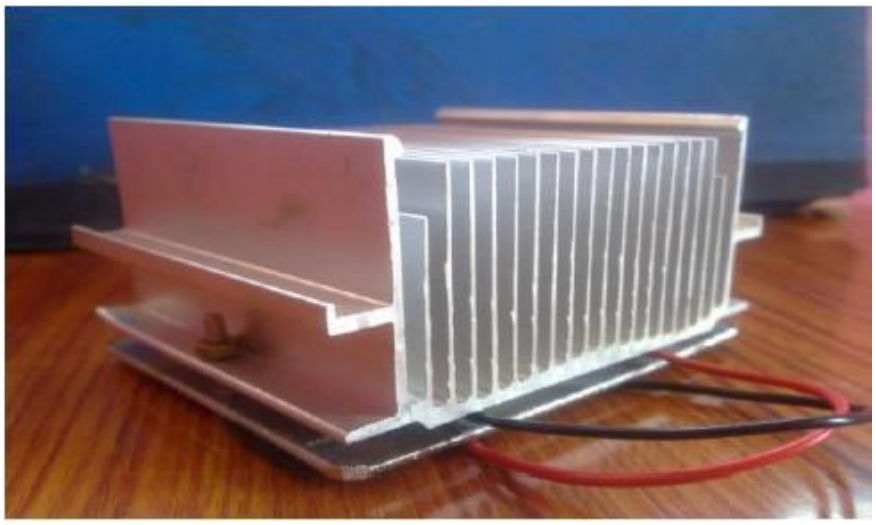

Fig 2. Thermoelectric power generator with fin

4.Result

S.No	Temp. of Source Plate (^{0}C)	Temp. of Source Plate (^{0}C)	Temp. Diff (^{0}C)	Voltage Produced (V)
1	35	28	7	0.89
2	40	32	8	1.2
3	45	36	9	1.6
4	50	40	10	2
5	55	41	14	2.3
6	60	45	15	2.5

We have conducted tests on the system and found the results by measuring the temperature with a thermometer and voltage with a voltmeter and tabulated them and we have drawn a graph between temperature difference and voltage.

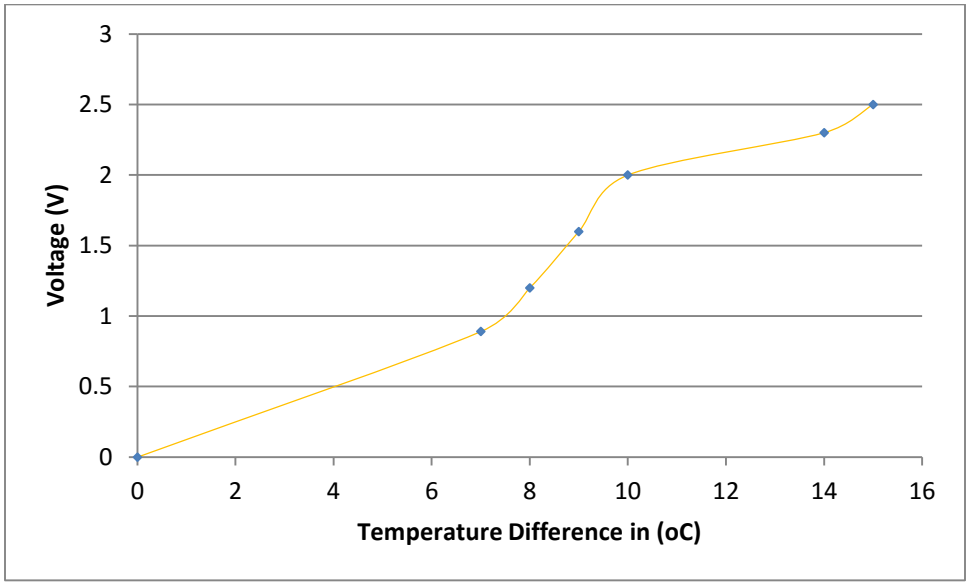

Fig 3.graph showing variation of voltage with temperature difference

5. Conclusion

We have found that there is a linear increase in the system as the temperature difference increases voltage produced also increases.

From this study we have learnt that for every 10 ^{0}C rise in the temperature difference there is an increase in voltage of 0.1632 V.

Reference

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