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Efficiency Calculation of a Thermoelectric Generator

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Abstract: ***Now a day, the world is experiencing global warming due to excessive energy into atmosphere. Today, a lot of research is being conducted on the ways to recover or reuse the energy losses. An experimental investigation has been carried out to identify the most suitable cooling system techniques to achieve a stable and sustainable power output. This paper depicts the working and efficiency calculation of a thermoelectric generator. The thermoelectric generator works on the Seebeck effect which is the temperature difference between two dissimilar electrical conductors or semiconductors producing a voltage difference between two substances. Thermoelectric cooler uses the heat waste from a number of sites and can generate electricity. The experiment is carried out at low cost with standard equipment and hence efficient in many ways.***

Keywords: Thermoelectric cooler; Thermoelectric generator; TEC; Efficiency; Seebeck effect

1. Introduction

The main purpose of thermoelectric generator is to generate electricity with the heat provided from the heat source. These thermoelectric generators are relatively low in cost and can be long-life when operated under safe conditions. However, thermoelectric generators have a lower efficiency compared to other heat generation techniques and devices. These devices can be used at different places where there is a wastage of heat and that heat can be used by TEC to generate small amount of electricity to power anything running at low volts.

Thermoelectric devices are small in size and low in cost which makes it easier to experiment on their efficiency for power generation. The efficiency can be used to compare with the efficiencies of other power generation devices and hence the price can also be compared when there is a requirement for economic power generation. These devices work on a simple effect proposed by Seebeck and hence would be easy to understand by undergraduates.

The purpose of interest in this paper and what makes it different from previous research is that this experiment costs very low and also the power generation and efficiency are more compare to previous experiments .this setup can also be incorporated in undergraduate thermoelectric lab and can be used as a demonstration for thermoelectric lecture.

2. Experimental Setup

A commercial thermoelectric cooler was used named TEC 12706 bismuth telluride with physical parameters of 40mm x 40mm x3.5 mm. the inner and outer looks of the device are as follows

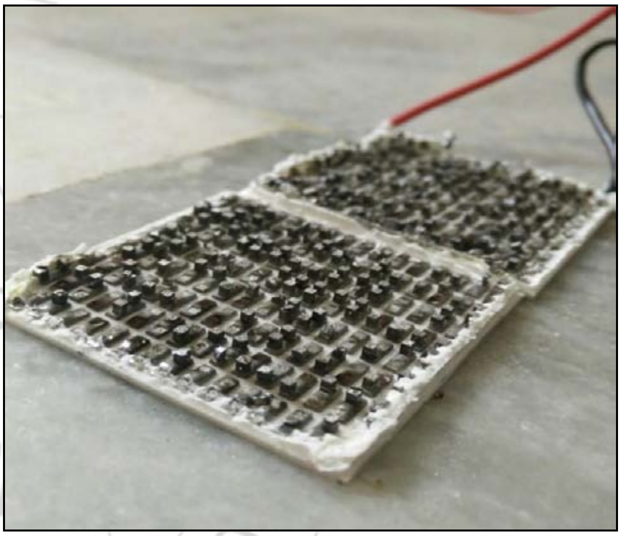

Figure 1: Inside a TEC.

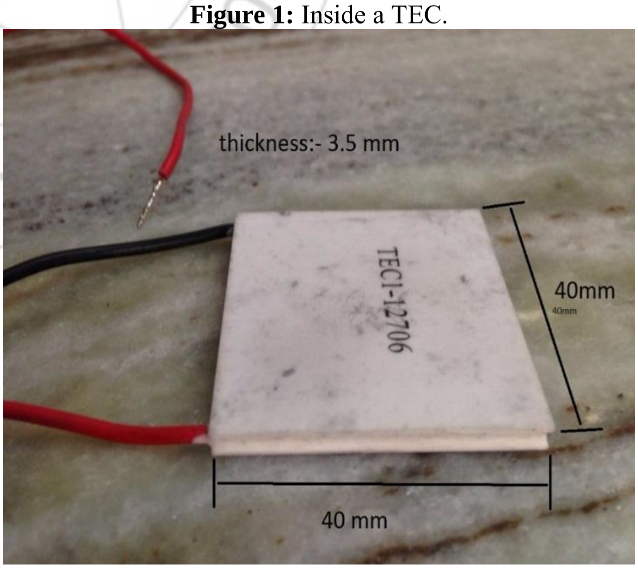

Figure 2: Thermoelectric cooler (TEC1-12706)

The TEC consists of 126 semi-conductors inside and the material is made of bismuth telluride and covered with Celinium. The TEC consists of hot side and cold side. Whenever heat is supplied to the hot side the TEC generates electricity.

The TEC was placed between the experimental setup in such a way that the hot side of the TEC touched the heat sink using a thermal paste and this heat sink was in direct contact with the torch of the candle which is used as the heat source. A heat dissipater is used to equally distribute the heat and keep the cold side cool.

Figure 3: Heat sink attached to the hot side of TEC

3. Efficiency Calculation

To calculate the efficiecny of TEC or TEG, firstly, efficiency by which a material is capable of generating power (Z) need to be calculated which is found out using the following formulae:

$$Z = \left[\frac{S_H - S_C}{\sqrt{\sqrt{\rho_H k_H} + \sqrt{\rho_c k_c}}}\right]^2$$

Then, the conversion unit is to be calculated using the below formulae:

$$M = \left[1 + \frac{Z}{2}(T_H + T_C)\right]^{1/2}$$

Finally, the ideal and optimum efficiency is found out using the formulae:

$$\eta_{ideal} = \left(\frac{T_H - T_C}{T_C}\right)\left[\frac{M - 1}{M + \frac{T_C}{T_H}}\right]$$

$$\eta_{opt} = \eta_{ideal} \text{ x } 100$$

Where,

η_{ideal}	=	Ideal Efficiency, %
η_{opt}	=	Optimum Efficiency, %
ρ_C	=	Electrical Conductivity for cold material, μ Ωm (12.6 μ Ωm for p-type Antimony Telluride)
ρ_H	=	Electrical Conductivity for hot material, μ Ωm (12.6 μ Ωm for n-type Bismuth Telluride)
K_C	=	Thermal Conductivity for cold material, W/mK (1.3 W/mK forp-type Antimony Telluride)
K_H	=	Thermal Conductivity for hot material, W/mK (1.8 W/mK forn-type Bismuth Telluride)
M	=	Conversion Unit
S_C	=	Seebeck Coefficient for cold material, μv/K (185 μv/K for p-type Antimony Telluride)
S_H	=	Seebeck Coefficient for hot material, μv/K (-228 μv/K for n-type Bismuth Telluride)
T_C	=	Temperature of cold side of TEC (K)
T_H	=	Temperature of hot side of TEC (K)
Z	=	Efficiency by which a material is capable of generating power, K^{-1}

4. Sample Calculations

From the experimentaion we found:
$T_H = 359.15$ K
$T_C = 338.15$ K

Hence,

$$Z = \left[\frac{-228 - 185}{\sqrt{\sqrt{12.6 \text{ X } 1.8} + \sqrt{12.6 \text{ X } 1.3}}}\right]^2 = 2119 \text{ K}^{-1}$$

$$M = \left[1 + \frac{Z}{2}(359.15 + 338.15)\right]^{1/2} = 859.529$$

Then the ideal efficiency is,

$$\eta_{ideal} = \left(\frac{T_H - T_C}{T_C}\right)\left[\frac{M - 1}{M + \frac{T_C}{T_H}}\right]$$

$$\eta_{ideal} = \left(\frac{359.15 - 338.15}{338.15}\right)\left[\frac{859.529 - 1}{859.529 + \frac{338.15}{359.15}}\right] = 0.0619\text{x}100 = 6.19\%$$

References

[1] Dhumal, Ganesh S., Deshmukh, P.A., Kulkarni, M. L. Experimental investigation of thermoelectric refrigeration system running on solar energy and development of mathematical model. International Engineering Research Journal (IERJ) Volume 1 Issue 5 pp.232-238, ISSN 2395-1621. (2015).

[2] Jalil, Mohd Izam Abd and Sampe, Jahariah. Experimental Investigation of Thermoelectric Generator Modules With Different Technique Of Cooling System. American Journal of Engineering and Applied Sciences, 6 (1), ISSN: 1941-7020, pp. 1-7. (2013).

[3] Joohansson.Thermoelectric Fan Powered by a Candle. (2013).

[4] Karaaslan, Salih, Calisir, Tamer, Yilmazoglu, M. Zeki, Yilmaz, Turgut O. and Baskaya, Senol. Investigation Of Thermoelectric Generator Locations In A Heat Cell. Novi Sad, Serbia : The 6th PSU-UNS International Conference on Engineering and Technology (ICET-2013),. Paper No. T.13-1.1, pp. 1-5. (May 15-17, 2013).

[5] Karri, M.Thermoelectric Power Generation System Optimization Studies. Clarkson University, New York. (2011).

[6] Mishra, S K, Satpathy, S and Jepsen, O. Electronic structure and thermoelectric properties of bismuth telluride and bismuth selenide. J. Phys.: Condens. Matter 9, Printed in the UK. pp. 461–470. (1997).

[7] O'Halloran, Steven and Rodrigues, Matthew.Power and Efficiency Measurement In A Thermoelectric Generator. American Society for Engineering Education. (2012) AC 2012-3976.

[8] Ono, K. and Suzuki, R.O. Thermoelectric power generation: Converting low-grade heat into electricity. JOM, 50, DOI: 10.1007/s11837-998-0308-4, pp. 49-51. (1998).

[9] Rawat, Manoj Kumar, Sen, Prasanta Kumar, Chattopadhyay, Himadri, Neogi, Subhasis. Developmental and Experimental Study of Solar Powered Thermoelectric Refrigeration System. International Journal of Engineering Research and Applications (IJERA), pp.2543-2547, Vol. 3. ISSN: 2248-9622. (Jul-Aug, 2013).

[10] Rowe, D.M. Thermoelectric Waste Heat Recovery as a Renewable Energy Source: International Journal of Innovations in Energy Systems and Power, Vol.1, Issue.1. (November, 2006).

[11] Rowe, D.M. Thermoelectrics, an environmentally-friendly source of electrical power. Renew. Energy, 16, DOI: 10.1016/S0960-1481(98)00512-6, pp. 1251-1256. (1999).

[12] Salamat, R.G. Thermoelectric Module for Low-Voltage Loads. Open Access Library Journal, 1:e1185 (2014).

[13] Takazawa, H., H. Obara, Y. Okada, K. Kobayashi and T. Onishi et. al., Efficiency measurement of thermoelectric modules operating in the temperature difference of up to 550K. Vienna : Proceedings of the 25th International Conference on Thermoelectrics, IEEE Xplore Press,. 10.1109/ICT.2006.331330. (Aug. 6-10, 2006).

[14] Zorbas, K.T., Hatzikraniotis, E. and Paraskevopoulos, K.M. Power and Efficiency Calculation in Commercial TEG and Application in Wasted Heat Recovery in Automobile. Odessa, Ukraine : Proceedings of the 5th European Conference on Thermoelectrics, (September 10-12, 2007).

[15] Zou, Helin, Rowe, D. M. and Min, Gao. Preparation and characterization of p-type Sb_2Te_3 and n-type Bi_2Te_3 thin films grown by coevaporation. J. Vac. Sci. Technol. A 19 (3), American Vacuum Society, pp. 899-903. (May/Jun 2001).