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Measurement of Power By Varying Load Resistance – Thermoelectric Generator

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Abstract: *For energy conversion between heat and electricity a thermoelectric technology , which gives power generation and electric refrigeration. The high performance of thermoelectric materials can be calculated by maximizing the Seebeck coefficient and electrical conductivity. The different thermoelectric materials perform at different temperatures. The operating temperature of Bi2Te3alloys is nearly 3300c to 5250c and PbTe alloys has an operating temperature of 5000C to 7000C. A thermoelectric module consists of thermo elements in series to increase the operating voltage and in parallel to increase the thermal conductivity. In this paper we have studied the variation in powerover load resistance, when four thermoelectric generators made from Bi2Te3, and PbTe are connected in parallel at hotside temperature of 500C and the output current and output voltages are measured as 440mA and 5V with each Thermo Electric Generator (TEG) used is TEP1-1264-1.5 with rated power 2W. By decreasing the load resistance from 10Ω to 1Ω the maximum current is 1.425A and the output voltage is constant. The power calculated for each load resistance is 2.2W, 2.4W and so on. The maximum power is 11.1 W at different temperatures. The corresponding graphs are drawn between loadresistance vs power, temperature vs power, output current vs power, and temperature vs load resistance.*

Keywords: *Thermoelectric devices, load resistance, power*

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I. Introduction

Solid-state thermoelectric devices are at present used in verity of applications ranging from thermocouple sensors to power generators in satellites, to handy air-conditioners and refrigerators. Thermoelectric energy transformation has been getting increased attention as a prospective candidate for waste-heat harvesting as well as for power generation from renewable sources. Efficient thermoelectric energy conversion critically depends on the performance of thermoelectric materials and devices. In space applications, Radio isotope thermoelectric generator are used. Due to attractive features like no moving parts, high reliability, long life thermoelectric materials are pretty good for applications in solid state cooling and electrical power generation [1-3]. The power factor in thermoelectric generator is calculated by,

$$P = S2\ \sigma \qquad (1)$$

Where S is the Seebeck coefficient σ is the electrical conductivity For power generation the materials like Bi, Sb, Te , Se are used. The operating temperature of Bismuth telluride is 3300C to 5250 C and Lead Telluride has an operating temperature of 5000C to 7000C[1-4]. At room temperature, bismuth telluride and its alloys are the best thermoelectric materials used for refrigeration. Generally thermoelectric generators consisting of bismuth telluride are widely used and the performance of this material can be improved by combining with other compounds like PbTe, Sb2Te3. The optical and electrical performance of lead chalcogenides(compounds of lead with tellurium, selenium, sulphur) is good. For power generation applications lead telluride is also the best thermoelectric material. For several NASA space missions , the PbTe based material has been used .

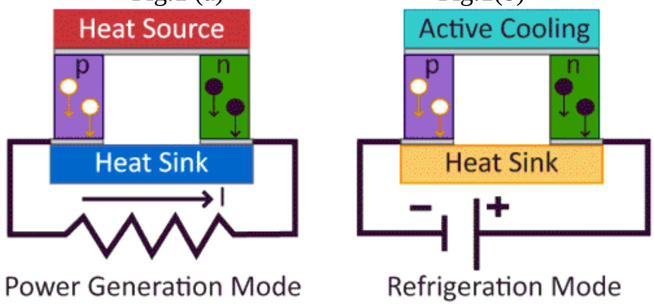
II. Thermoelectric Devices

For converting temperature difference into electricity thermoelectric devices are using Seebeck effect. In waste heat recovery applications also thermo electric devices are used. With increase of temperature difference between the two ends of thermoelectric generator Seebeck coefficient was reduced. The relation between the voltage and temperature difference is given by ,

$$V = S\ \Delta T \qquad (2)$$

where S is the Seebeck coefficient and V is the voltage across the circuit , ΔT is the difference in temperature between hot and cold junctions. When p and n-type materials are connected Fig:1 (a) shows the power generation mode and Fig:1(b) shows the refrigeration mode. The Thomson effect and Seebeck coefficient are not temperature independent but they are temperature dependent.

Fig:1 (a) Fig:1(b)



III. Thermoelectric Generator

As we know that each thermoelectric module consists of p-type and n-type terminals which are connected to hotside and cold side.These n-type and p-type pellets can be connected in series as well as in parallel.The performance of thermoelectric generator increases the temperature difference on both sides like cold side and hot side increases. As heat is increased in thermo electric legs, their electrical performance increases. The electrical performance of thermo electric power generator is increasing the material figure of merit , [5,6] zT is around 1 for thermoelectric devices made of bismuth telluride or tin telluride alloys at room temperature applications and at higher temperatures applications. From theoritical analysis, when the electrical internal resistance is equal to the external load resistance, maximum output power is produced. With increasing the temperature difference between cold side and hot sides of TEG , the performance of TEG can be increased. In spite of operating temperature, when the temperature is fixed , the TEG produces the similar voltage , current and power outputs.

IV. Experimental Set Up

The thermoelectric module TEP1 – 1264 -1.5 is Bismuth telluride based thermoelectric generator. This module can generate more power due to difference in temperature. The size was 40 mm x 40 mm. Fig:2 represents the thermoelectric device used for testing model TEP1-1264-1.5 .

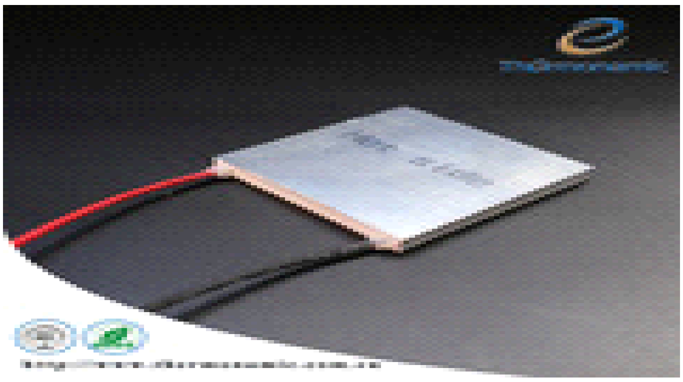


Fig:2 Thermoelectric device used for testing (model TEP1-1264.1.5)

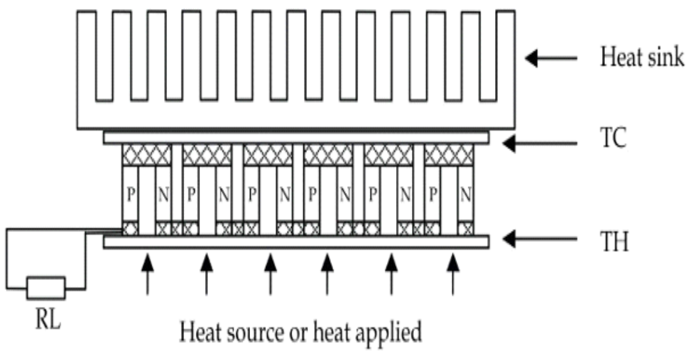


Fig:3 Schematic diagram of thermoelectric generator with load.

Fig:3 shows that each thermoelectric module consists of p-type and n-type semiconductors that acts as thermoelectric device which are arranged in series electrically and in parallel thermally with load and the heat source and heat sink can also be applied to this thermoelectric module. Each p-type and n-type is referred to as a thermocouple. A thermoelectric device containing many such elements produces a voltage. In fig:3 TC and TH are the temperatures of cold side and hot side and RL is the load resistance applied to the circuit [8-10]. The magnitude of the voltage depends upon the thermoelectric materials like bismuth telluride and lead telluride.[11,14]

Fig:4 Experimental set up of thermoelectric generator with cooling fans and heat sink.

Fig:4 shows that the thermoelectric generator is between and hot side and cold side. For temperature measurement in between hotside and coldside a temperature system is arranged. The output of the TEGs can be connected to an electrical load. Maintaining the temperature across the thermoelectric device to the desired value and it is possible to obtain the power value by varying load resistance at different values, when four TEGs are connected in parallel with TEP1 – 1264-1.5 . The power can be measured by the product of output voltage and output current.

V . Results,Graphs And Discussions

Table:1 The values of input , output voltages, current and power

S. NO.	Temperature(0C)	Input voltage (V)	Output Voltage (V)	Load resistance (Ω)	Output current (mA)	Power (W)
1	50	4.67	5	10	440	2.2
2	60	4.60	5	9	490	2.4
3	70	4.53	5	8	530	2.6
4	80	4.50	5	7	610	3.0
5	90	4.4	5	6	700	3.5
6	100	4.2	5	5	770	3.8
7	110	4.1	5	4	920	4.6
8	120	3.96	5	3	1040	5.2
9	130	3.8	5	2	1360	6.8
10	140	3.0	5	1	1425	11.1

A graph is drawn between load resistance and the power generated then it is represented in Fig: 5. as load resistance is decreasing from 10Ω, then the power will be increasing at different temperatures.

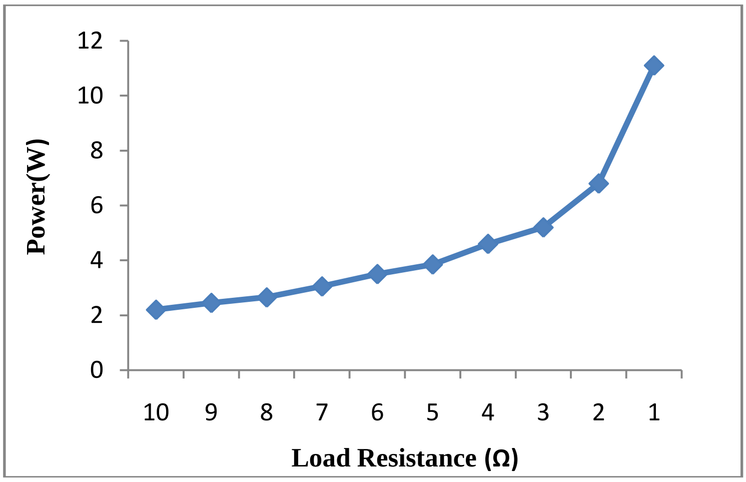


Fig:5 Power as a function of the load resistance at different temperatures.

The power will be , P=11.1W at R=1Ω, at Temperature of 1400C.A graph is also drawn between temperature and power generated . So as temperature increases the power is also increasing. At 500c the power generated will be 2W and at 60, 70,80,90,100,110,120,…… the output power is calculated was 2.45W, 2.65W, 3.05W, 3.5W, 3.85W, 4.6W,5.2W,6.8 W and 11.1 W and the graph is shown in Fig:6

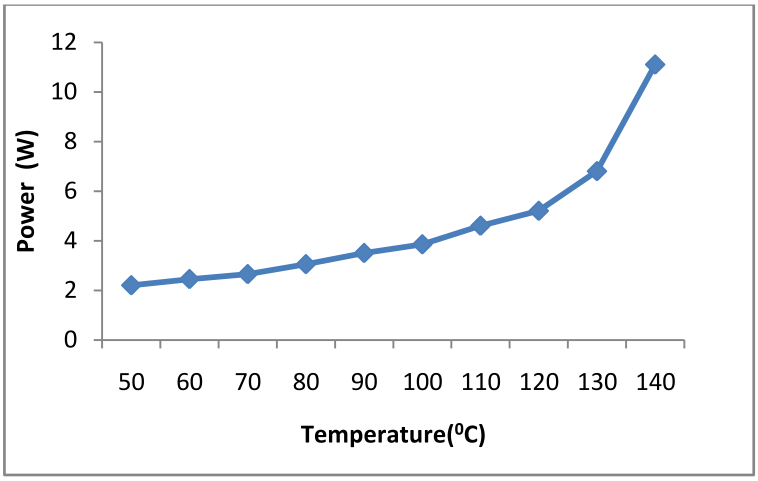


Fig: 6 Power as a function of temperature .

The power will be maximum of 11.1 W at temperature 1400C.A graph is also drawn between output current and the power generated at different temperatures of hot side at 500C, 60, 70, 80….. As output current increasing, the power also increases and the graph is shown in Fig: 7

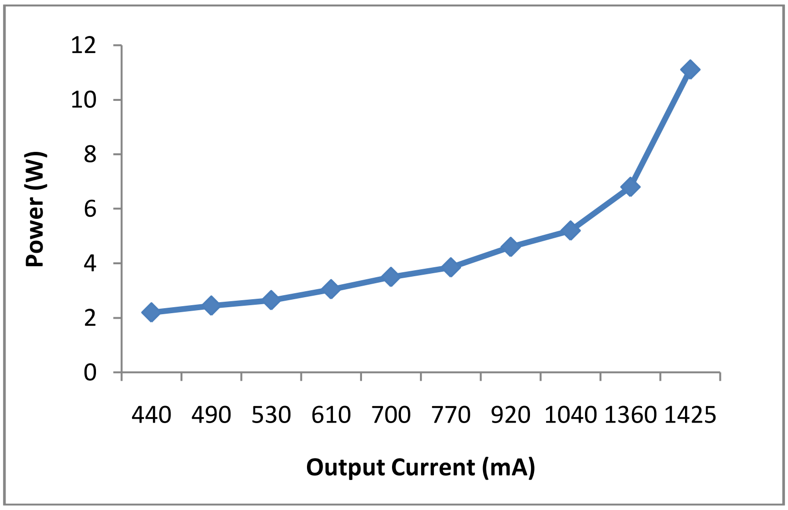


Fig:7 Power as a function of Output current

At temperature of 1400C , the current will be maximum of 1.425A and the maximum power will be 11.1 W .

VI. Conclusion

When thermoelectric generators are connected in parallel , we can also measure the power generated by varying load resistance at different temperatures for different thermoelectric materials like Bi2Te3, PbTe. By taking the Bismuth Telluride thermoelectric device (TEP1-1264-1.5) and connecting four TEGs in parallel , at different temperatures the output power generated, output current , output voltage are measured . At load resistances 10Ω to 1Ω the power generated will be maximum of 11.1W at 1400C observed and the corresponding graph is plotted output power as a function of load resistance. When decreasing the load resistance , the power will be increasing. As We can also draw a graph of power as a function of temperature. At temperature of 1400C, we plot a graph of power as a function of output current, maximum power will be 11.1W and the maximum current will be 1.425A. The thermoelectric performance of TEG depends upon temperature of cold and hot sides and thermal and electrical conductivities of materials. Therefore the overall performance of TEG can be increased with temperature difference between cold and hot sides of thermoelectric generator.

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