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A Design of Thermoelectric Cooler and Optimization

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Abstract

Design, analysis and optimization of a thermoelectric refrigerator was carried out in this work the systems use thermoelectric "peltier" refrigerators (thermoelectric modules) to produce cooling or heating. The design calculation are find the performance curve of the thermoelectric module with the purpose of is find by simulation. Simulation results were compared with the practical data. The system simulation shows that exist a cheapest heat sink used for the thermoelectric refrigerator. the thermoelectric refrigerator with an air-cooled heat sink with thermal resistance 0.2515°C/W. Comparison was done between Bismuth telluride (Bi_2Te_3) and Antimony telluride(Sb_2Te_3) for the thermoelectric module. It was found that the bismuth telluride (Bi_2Te_3) due to its low thermal conductivity and high See back coefficient at room temperature has higher figure of merit (Z) and thus performed better as compared to Antimony telluride. The design be capable of be ready either on basis of the highest value of the cooling capacity, or on the basis of the most excellent heat sink technology existing.

Keywords: Thermoelectric Module, Heat Sink, Thermoelectric Refrigerator.

I. INTRODUCTION

Now a days, the global rising require for refrigeration, e.g. air-conditioning, food preservation, vaccine storages, medical services, and cooling of electronic devices, led to use of more electricity and as a effect release of CO_2 all over the world [1] which it is contributing factor of global warming on climate change. Thermoelectric Refrigerator(TER) is new option for the reason that it can convert electrical energy into valuable cooling , is usual to play an main role in today's energy challenges then, TER are really required, mostly for developing countries there long life and low maintenance are required [2]-[7].

TER are apply of TEC on Peltier effect for removing heat via DC current apply across two different materials cause a temperature degree of difference [8]. Since TEC can be analyzed by Joule heat, which is called heat rejection (qh), from TEC hot side larger than the heat absorption (qc), into TEC cold side. A thermoelectric cooler made of a number of N & P pellets attached electrically in series and thermally in parallel between two ceramic plates as shown in Fig. 1.1. The bottom plate is bonded to a heat sink and, with DC current , heat is pumped starting the top plate to the bottom plate and into the heat sink.

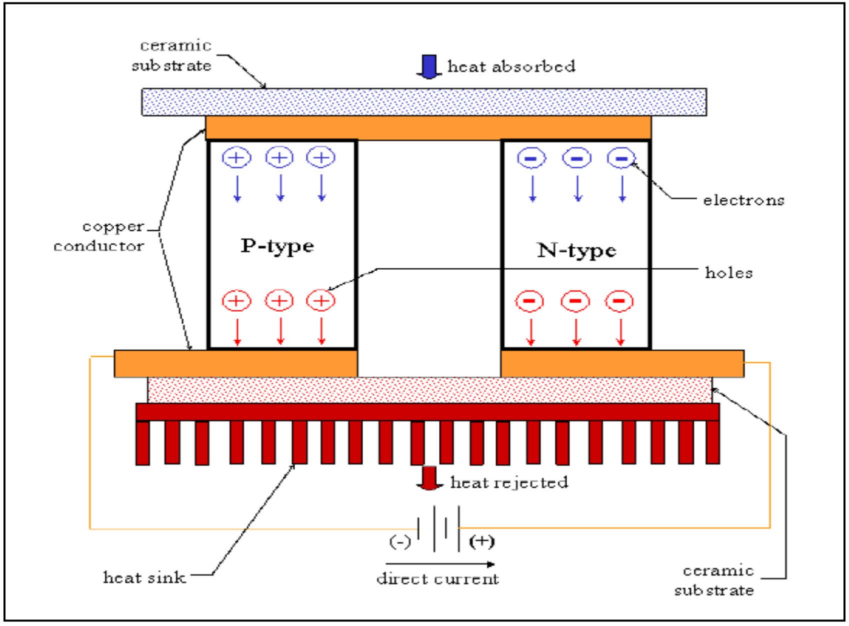

Fig. 1: The Thermoelectric Cooling System

II. MATERIAL

A. Bismuth Telluride and its Alloys:

An ideal thermoelectric material is not only assured by a high figure of merit, but also by the temperature range, where these high values are achieved. In practical situations, each material has its ideal operation temperature range, thus the choice of the material is strongly affected by the intended use.

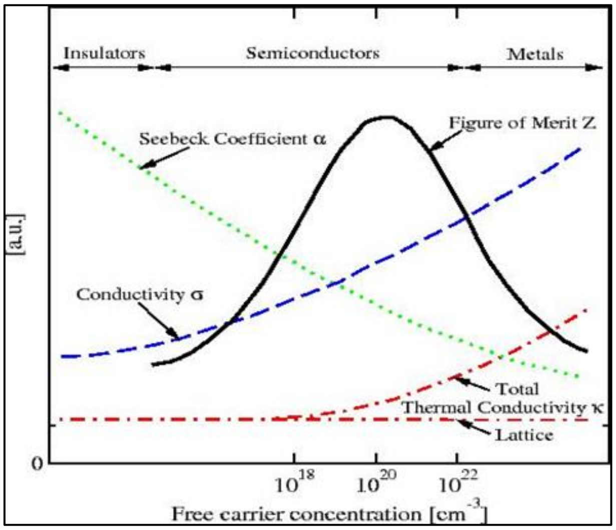

Fig. 2: Seebeck Coefficient, Conductivity, Thermal Conductivity, And Figure Of Merit With Respect To Free Carrier Concentration. [9]

A coefficient of performance of a thermoelectric refrigerator depends on the different properties of a thermoelectric material such as thermal conductivity, resistivity, carrier concentration and seebeck coefficient. The above mentioned properties are dependent on the temperature of the working environment. Bismuth Telluride and its Alloys provide the good figure of merit at room temperature they can be successfully used in cooling application. Silicon-Germanium performs better at elevated temperature thus it can be used for power generation application. The methods of increasing the favorable properties required for better performance of the thermoelectric refrigerator were outlined.

III. THERMAL DESIGN

Thermoelectric refrigerator has been widely used in military, aerospace instrument, and industrial or commercial products, as a cooling device for specific purposes. This technology has existed for about 40 years. Many researchers are concerned about the physical properties of the thermoelectric material and the manufacturing technique of thermoelectric modules. In addition to the improvement of the thermoelectric material and module, the system analysis of a thermoelectric refrigerator is equally important in designing a high-performance thermoelectric refrigerator.

Table – 3.1
Show The Detailed Specification Of The Thermoelectric Module [10].

Sr No	*Module*	*RC12-8*	*Sr No*	*Module*	*RC12-8*
1	*Material*	*Bismuth*	*7*	*Q_{max}(Watt)*	*68.54*
		Telluride(Bi_2Te_3)			
2	*I(Amp)*	*4.4*	*8*	*Top W (mm)*	*40.1*
3	*R_F*	*0.2515°C/W*	*9*	*Top L (mm)*	*44.7*
4	*V(Volts)*	*12.17*	*10*	*BaseW (mm)*	*40.1*
5	*T_h(°C)*	*62.31*	*11*	*Base L (mm)*	*40.1*
6	*ΔT_{max}(°C)*	*66*	*12*	*Height (mm)*	*3.6*

B. System Design Analysis Of Thermoelectric Refrigerator:

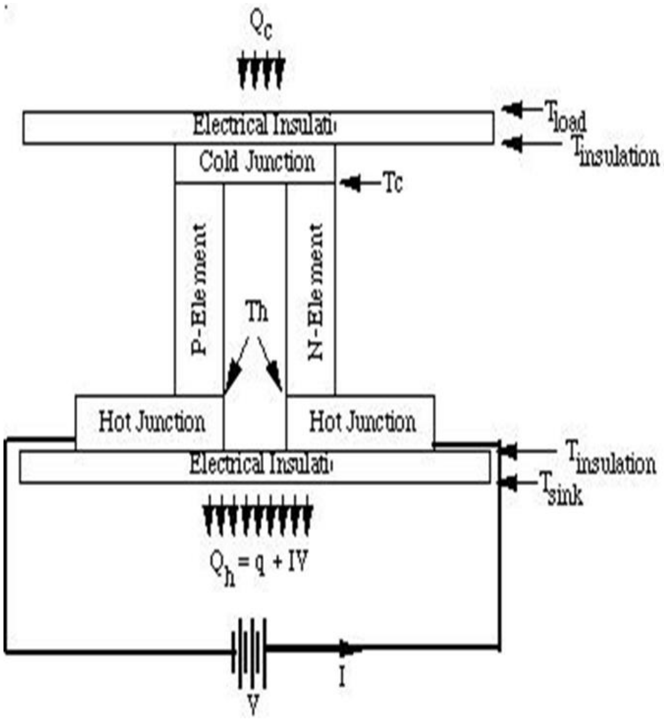

Fig. 3.1: Thermal Network Model Of A Thermoelectric Refrigerator

The thermal performance of a thermoelectric refrigerator depends going on the thermoelectric module performance as well as the heat sink design. The heat released from a heat element is absorbed through the cold side of a thermoelectric module and pumped to the hot side by the module. The Pumped heat mutually with the input power towards the module is next deserted to the ambient from side to side a heat sink. therefore, draw a thermal system to characterize the heat transfer method in a thermoelectric refrigerator as shown in Fig. 3.1, assuming no contact resistance. The total heat transfer from the 59 heat sink to the ambient QH depends on the thermal resistance of the heat sink RF which is defined as

$$Q_H = \frac{T_H - T_a}{R_F} \qquad (5.32)$$

C. Flow Chart:

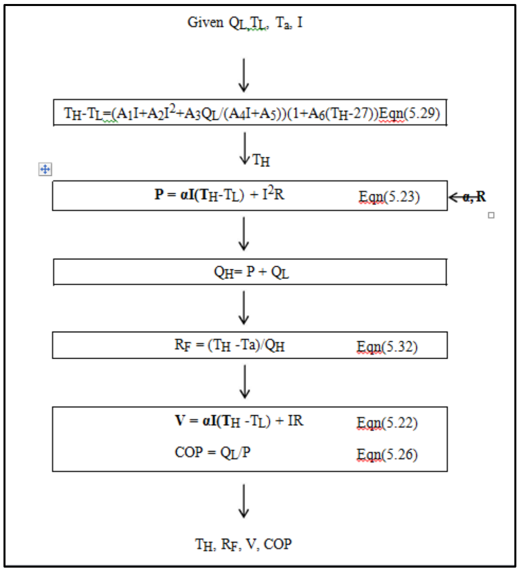

Fig. 3.2: Flow Chart

The system analysis of a thermoelectric refrigerator can be carried out according to the flowchart shown in Fig. 3.2

Table - 3.2
cheapest Heat Sink At Rfmax For Various Capacities

I	R_F *at* Q_L*=0 W*	R_F *at* Q_L*=5W*	R_F *at* Q_L*=10W*	R_F *at* Q_L*=15W*
0.5				
1	*0.93*			
1.5	*2.02*	*0.33*		
2	*2.09*	*0.84*	*0.15*	
2.5	*1.97*	*1.03*	*0.42*	*0.04*
3	*1.80*	*1.06*	*0.55*	*0.20*
3.5	*1.61*	*1.02*	*0.59*	*0.28*
4	*1.42*	*0.94*	*0.58*	*0.31*
4.5	*1.23*	*0.83*	*0.53*	*0.31*
5	*1.05*	*0.72*	*0.47*	*0.28*
5.5	*0.87*	*0.60*	*0.40*	*0.24*
6	*0.70*	*0.49*	*0.32*	*0.19*

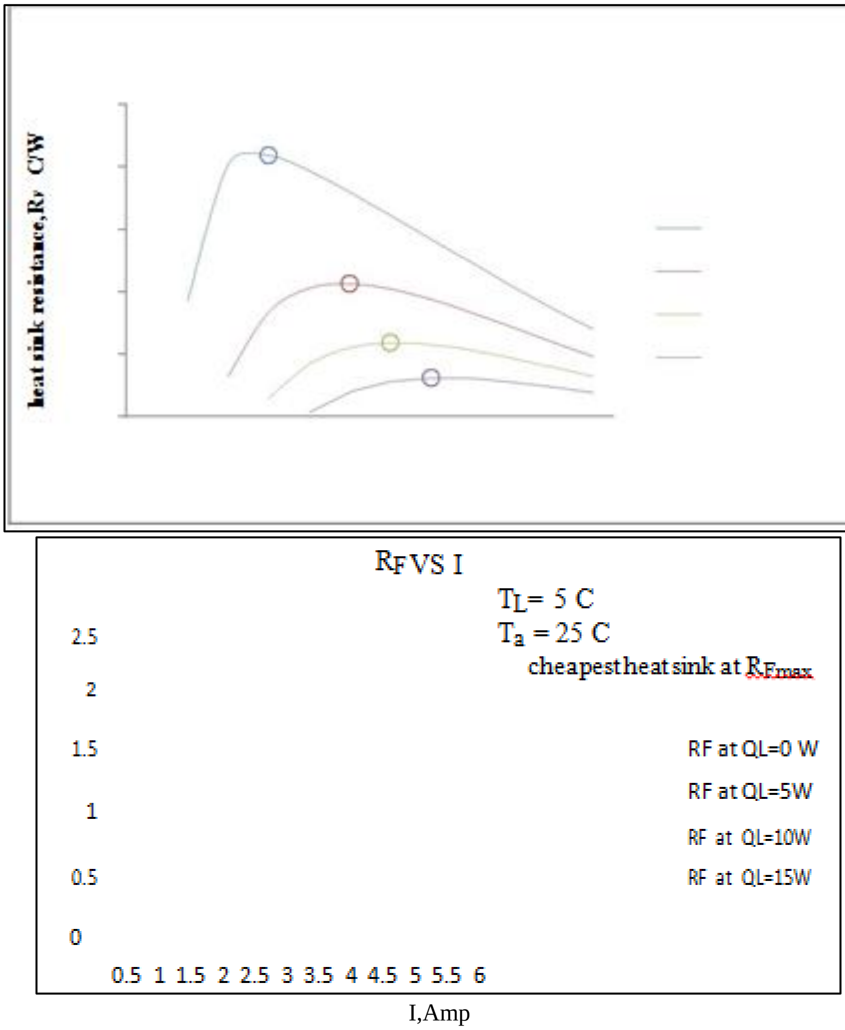

Fig. 3.3: Cheapest Heat Sink At Rfmax For Various Capacities

Fig. 5.5(a) shows that the required heat sink thermal resistance RF varies with the input current I for a fixed cooling capacity QL. RF first increases with increasing I, reaches a maximum value, and then decreases with increasing I. The maximum value of RF represents a poor performance heat sink with larger thermal resistance, but corresponds to a cheapest heat sink. The system simulation is shown to coincide with the experimental data of a refrigerator using a heat sink with thermal resistance 0.2515 °C/W. The system simulation provides various plots for system design application. It is found that the coefficient of performance

(COP) for the 15 W capacity and at TH = 45°Cdegree is 0.358 and 0.242 for Bi2Te3 and Sb2Te3 respectively. The optimum current for Bi2Te3 and Sb2Te3 is 2.5 and 3.1 amps respectively.

IV. OPTIMIZATION

Table - 4.1
Simulation Results At The Condition Of Optimal COP

Iopt	*1.5*	*2*	*2.5*	*3*	*3.5*	*4*	*4.5*	*5*	*5.5*
COPopt		*0.72*	*0.44*	*0.30*	*0.20*	*0.14*	*0.10*	*0.07*	*0.04*

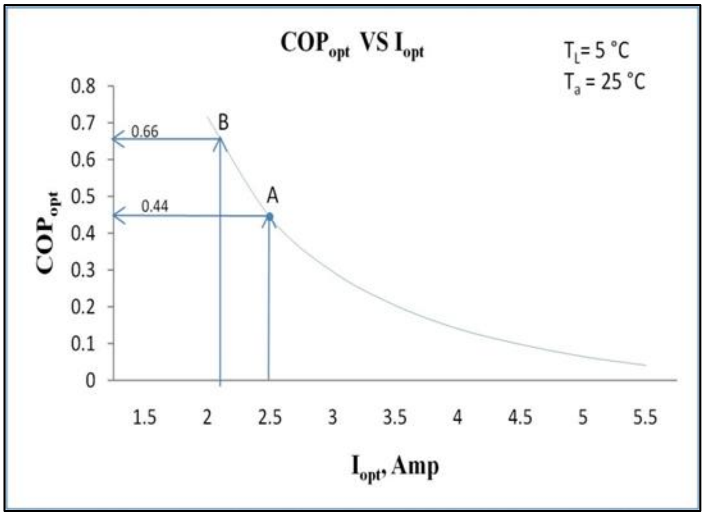

Fig. 4.1: Simulation Results At The Condition Of Optimal Cooling Capacity And Optimal COP

Table - 4.2
Simulation Results At The Condition Of Optimal Heat Sink Resistance

Iopt	*1.5*	*2*	*2.5*	*3*	*3.5*	*3.7*	*4*	*4.3*	*4.5*
RFopt		*0.22*	*0.44*	*0.62*	*0.74*	*0.78*	*0.84*	*0.88*	*0.90*

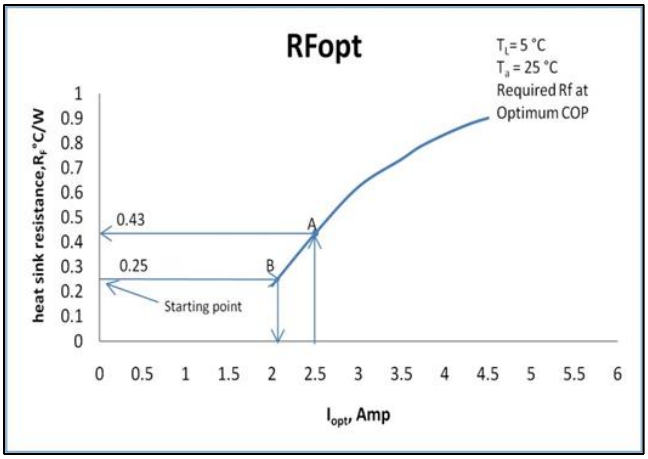

Fig. 4.2: (A) Heat Sink Resistance

Table - 4.3
Simulation Results At The Condition Of Optimal Voltage

Iopt	*1.5*	*2*	*2.5*	*3*	*3.5*	*4*	*4.5*	*5*	*5.5*
Vopt	*4.66*	*6.76*	*8.55*	*11.23*	*13.82*	*17.13*	*21.19*	*25.32*	*28.69*

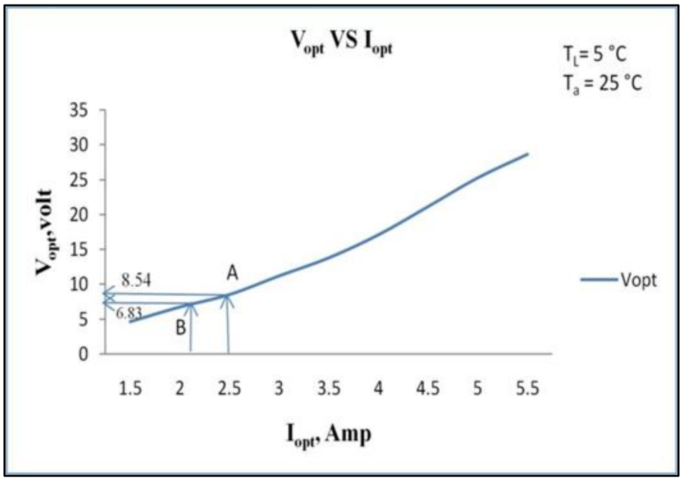

Fig. 4.2: (B) Voltage

Fig. 4.2: (A) & (B) Simulation Results At The Condition Of Optimal Heat Sink Resistance &Voltage

A. System Design Based On The Maximum Cooling Capacity Attainable:

It is interesting to see that, in addition to the condition of optimal COP, there also exits a maximum value for the optimum cooling capacity, denoted as Qopt, as shown in Fig. 4.1. If both the optimum COP and the maximum cooling capacity are desired, we can start from Fig. 4.1 for the design of a thermoelectric refrigerator. By locating the maximum value of Qopt at Point A, we then determine an Iopt. For the thermoelectric module RC12-8 used in the present calculation Iopt 2.5A for the maximum value of Qopt at 9.82 W. From Fig. 6.8(b), we determine COPopt as 0.44. From Fig. 4.2(a), we find that the required heat sink resistance RFopt at Iopt is 0.43 °C/ W. The required voltage for the thermoelectric module Vopt at Iopt is 8.54V from Fig.4.2 (b).

B. System Design Based On The Best Heat Sink Technology Available:

As mentioned previously, the best heat sink with a smallest RF can provide a best performance of the thermoelectric refrigerator. Hence, the system design can also be made on the basis of the heat sink technology available. In this case, the design will start from Fig. 4.2(a). For example, if the heat sink available has a RF value at 0.2515°C/W as the one used in the present study, then we can determine the optimal current Iopt to be 2.1Amp (Point B). From Fig. 4.1, we found that the optimal cooling capacity Qopt is 9.57 W which is slightly less than the maximum value 9.82 W at Point A. From Fig. 4.1, COPopt is around 0.66 which is much larger than the COPopt at Qopt (Point A).From Fig. 4.2(b), the voltage to the thermoelectric module RC12-8 at Iopt 2.1A is 6.83V. The above two design examples are used to illustrate how to implement the system simulation results in the design of a thermoelectric refrigerator.

V. CONCLUSION

1) The performance of a thermoelectric refrigerator is dependent on the figure of merit (Z), the figure of merit is the function of Seeback coefficient, resistance and thermal conductivity of the material
2) The thermal resistance of heat sink is used as one of the key parameters in the design of a thermoelectric refrigerator. The system simulation results show that there exists a cheapest heat sink with the highest thermal resistance for the design of a thermoelectric refrigerator.
3) For the thermoelectric module RC12-8 used in the present study, the required heat sink resistance at cold-end temperature 5°C changes from 0.43°C/W for the condition of the cheapest heat sink to 0.2515°C/W for the condition of the best available heat sink, about 42% increase in heat sink performance. However, the optimal COP increases from 0.44 for the cheapest heat sink to 0.66 for the best available heat sink, about 43% increase in COP. There is only a 2.7% drop in the cooling capacity for the best available heat sink design.

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