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Research Article

Design, Fabrication and Analysis of Thermo Electric Refrigerator

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Abstract

Refrigeration is the process of removal of heat from a body at lower temperature and sending it to surroundings. The present day refrigeration devices use refrigerant gases like Freons to do refrigeration which result in release of CFCs in to atmosphere which thereby result in depletion of ozone layer. But by using Thermo electric refrigeration this impact can be reduced. This project deals with design, fabrication and analysis of Thermo electric refrigerator. This refrigerator contains thermoelectric modules, Switched mode power supply equipment, Heat sinks, exhaust fans and temperature controlling switches. This project also includes the analysis of this refrigerator. Thermo electrics has a lot of scope in refrigeration, electric generators etc.

Keywords: *Thermo electric modules, Heat sinks, Thermal Analysis, Peltier cooler, CFCs, Refrigeration.*

1. Introduction

Refrigeration is the process of heat removal from a space in order to bring it to a lower temperature than surrounding temperature.

In this context, "Peltier cooling module" which works on thermo electric refrigeration, aims to provide cooling by using thermoelectric effects rather than the more prevalent conventional methods like 'vapour compression cycle' or the 'vapour absorption cycle'.

There are three types of thermoelectric effect: Seebeck effect, Peltier effect, Thomson effect. Peltier refrigerator works on the peltier effect which states that when voltage is applied across two junctions of dissimilar electrical conductors, heat is absorbed from one junction and heat is rejected at another junction.

Thermoelectric cooling uses the peltier effect to create a heat flux between the junction of two different types of materials. A petier cooler , heater, or thermo electric heat pump is a solid state active heat pump which transfers heat from one side of the device to the other, with consumption of electric energy, depending on the direction of the current. Such an instrument is also called a peltier device, peltier heat pump, solid state refrigerator, or thermo electric cooler. It can be used either for heating or for cooling, although in practice the main application is cooling. It can also be used as a temperature controller that either heats or cools. Many researchers and companies are trying to develop peltier coolers that are cheap and efficient.

A Peltier cooler can also be used as a thermo electric generator. When operated as a cooler, a voltage is applied across the device, and as a result, a difference in temperature will build up between the two sides. When operated as a generator, one side of the device is heated to a temperature greater than the other side, and as a result, a difference in voltage will build up between the two sides (the seebeck effect). However, a well-designed peltier cooler will be a mediocre thermoelectric generator and vice versa, due to different design and packaging requirements.

2. Working of Peltier modules

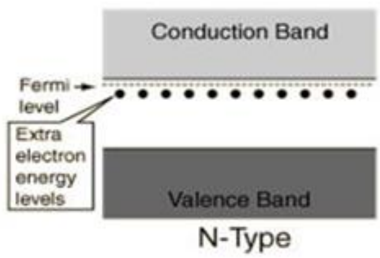

Fig.1 N-type semi conductor Energy band diagram

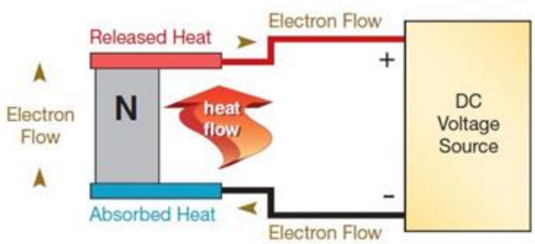

Fig.2 Heat Flow diagram

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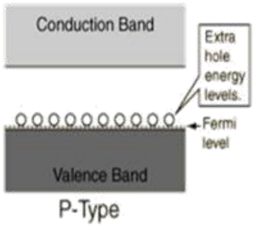

Fig.3 P-type semi conductor Energy band diagram

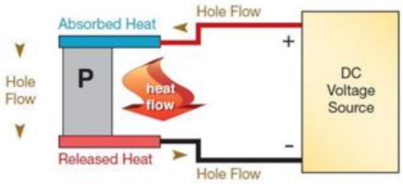

Fig.4 Peltier cooling with P-type semiconductor

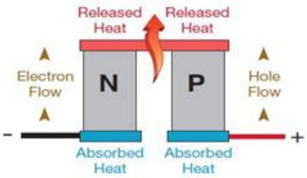

Fig.5 Peltier cooling by couple of N&P type

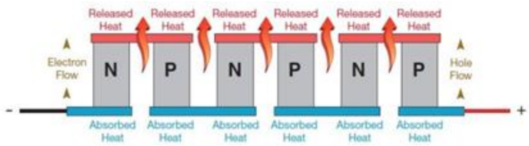

Fig.6 Peltier cooling by multiple pallets

2.1 Fabrication of Peltier Refrigerator

For producing thermoelectric effect couples of P and N type semiconductors are connected in series by metal plates. By doing this is absorbs the heat from one side and releases the heat to another side.

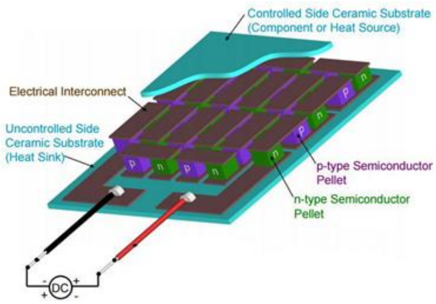

Fig.7 Construction of a single stage thermoelectric module

A typical TEC module comprises of two highly thermally conductive substrates (Al_2o_3, AIN, BeO) that serve as HOT/Cold plates. An array of p-type and n-type semiconductor (Bi_2Te_3, Sb_2Te_3,Bi_2Se_3) pellets are connected electrically in series sandwiched between the substrates. The device is normally attached to the cold side of the TEC module, and a heat sink which is required for enhanced heat dissipation is attached to the hot side.

Solder is normally used to connect the TEC elements onto the conducting pads of the substrates.

2.2 Fabrication of Thermo electric Refrigerator Materials Required

CRCA sheets of 3mm thickness, Glass wool, Door hinges of shaft hole type, Door handle, Door gaskets, 2 peltier modules(TEC 12706), 2 hot side heat sinks made of (Aluminium alloys like 1050A ,6060,6063),2suction fans, paper foam separators, 3mm fasteners, Temperature control switches with temperature sensors, Electrical wires,12V,10Amps type power supply, Insulation tapes, Spray paint, Thermal paste.

Heat sink Design in Solid works: This phase includes the designing of isolation box, now the dimensions are decided then a solid model is created by using solid works.

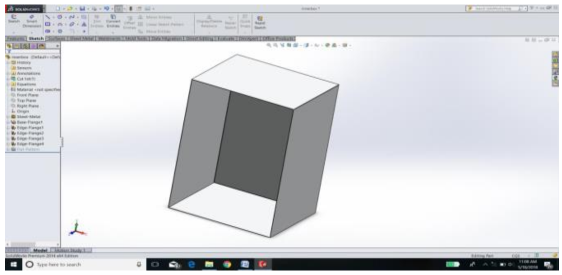

Fig.8 Inner Box

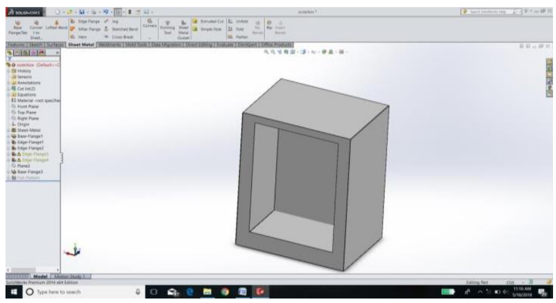

Fig.9 Outer Box

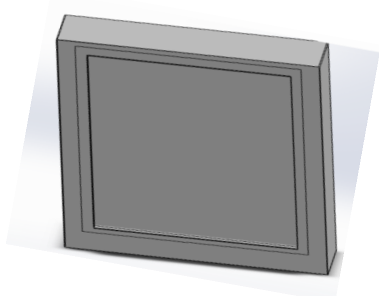

Fig.10 Design of door

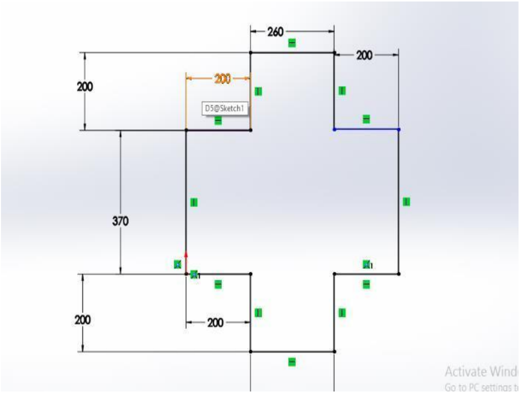

Fig.11 Development of Inner Box

The Heat sink should be designed in such a way that heat generated at the hot side of the peltier module should be carried out by forced convection, but during calculation it is assumed that heat dissipation should is done by natural convection.

Manufacturing of Isolation Box

The CRCA Sheet is bent in the form of a tray for mounting purpose by using CNC Brake press.

Fig.12 OMADA Brake press Machine

For manufacturing refrigerator Isolation Box, the box is made by using cold rolled cold annealed sheets. Cutting of sheets is done by using Brake press machine.

Fig.13 Manufactured Isolation Box

Assembling of peltier modules

Peltier Junction cooling Assembly, Thermo electric heat pump, Peltier junctions are thermo electric heating and cooling devices that feature reliable solid state temperature control.

Fig.14 TEC Assembly

Fixing of Peltier modules to Isolation Box

Use the colour coding of the positive (red) and negative (black)wires. Place the module on a flat surface so that the wires are pointing towards you with the positive (red) wire on the left hand side and the negative (black) wire on the right hand side .In this case the cold side will be facing down and Hot side will be facing up towards you. Connect the module to a power supply ensuring the polarity is correct. Connect Red wire to positive terminal and black wire to negative terminal. Now apply a voltage to the device. Take care about which side is cold and which side is hot. Terminate power supply as soon as temperature differential is observed. SMPS type of power source is used. Two peltier modules are connected in parallel connections to have some potential difference and two sensors for measuring temperatures of hot and cold side. A water proof sensor which is connected to W1209 is place at the cold side of peltier module. Then all the suction fans and exhaust fans are connected in parallel to the other output of power supply unit.

Fig.15 TEC Modules

Circuit of Thermo Electric refrigerator

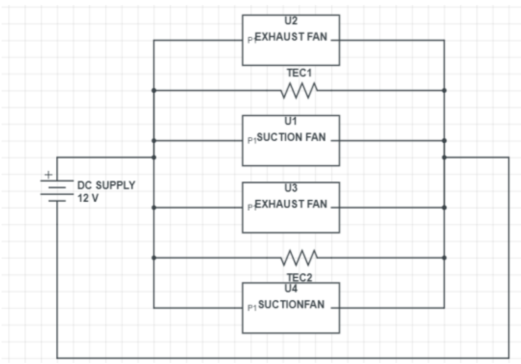

Fig.16 Thermo Electric Refrigerator

Fig.17 Heat sink attached

2.2 Governing equations and performance

The cooling capacity Q_1 results from the energy balance at the cold side of the thermoelectric refrigerator. When a current, I, is passed through the couple, there is Peltier cooling at the source equal to, (αp – αn)IT1*αp and are the Seebeck coefficients of the two branches which, of course, should have opposite signs. This cooling effect is opposed by heat conduction at the rate, where K_p and K_n are the thermal conductance of the branches. The cooling is also opposed Joule heating within the thermo elements. It is easily shown that half of the Joule heating.

m = sqrt (hp/kA) (1)
$Q_{remaining\ surface} = hA(T_s - T_a)$ (2)
$Q_{possessed\ by\ the\ fins} = mc(T_f - T_i)$ (3)
Effectiveness = $(Q_{actual} / Q_{without})$ (4)

The expression for cooling power is

$$Q1 = (\alpha p - \alpha n)IT1 - (T2 - T1) * (Kp + Kn) - [I^2(Rp + Rn)]/2 \quad (5)$$

The expression for power consumed is

$$W = (\alpha p - \alpha n).\ I.(T2 - T1) + I^2\ (Rp + Rn) \quad (6)$$

$$COP = Q1/W \quad (7)$$

Expression for Maximum cooling power is

$$Q1 = (\alpha_p - \alpha_n)IT1 - (T2 - T1)*(K_p + K_n) - [I^2(R_p + R_n)]/2$$

To find the maximum cooling power, differentiating Q_1, with respect to I and equating it to 0,

$$d\ Q1/d\ I = 0 \quad (8)$$

By, solving above equation, we can get current required for maximum cooling power,

$$I_{max} = (\alpha_p - \alpha_n)*T1 / (R_p + R_n) \quad (9)$$

Value of maximum cooling power, corresponding to

$$Q_{max} = (\alpha^2 * T1^2)/(2*R) - K*(T2 - T1) \quad (10)$$

Here, $\alpha = \alpha_p - \alpha_n$ $K = K_p + K_n$

$R = R_p + R_n$

Z = α2 /R.K and in substituting in Q_{max}

$Q_{max} = [(Z.T_1^2)/2 - (T2 - T1)].K$

Value of COP at maximum cooling power,

$$COP_{max} = [(Z.T_1^2)/2 - (T2 - T1)] / Z.T2.T1 \quad (11)$$

We can see from the above equations of Q_{max} and COP_{max} that, it solely depend on Z and the temperatures of the source and sink. So, Z is known as the figure of merit for thermocouple. Z has the dimensions of inverse temperature and it is more usual nowadays to specify the dimensionless figure of merit, which is equal to ZT_m at a mean temperature T_m.

$z = \alpha^2/R.K$ and $zT_m = \alpha^2.\ T_m / R.K$

Here ,R is the electrical resistance , which is equal to (ρ.l)/(A) or l/σ.A·

Since, length l and area A are not material properties, one can write figure of merit as,

$Z = (\alpha^2 * \sigma)/K$

In practice, ZT represents the efficiency of the N-type and P-type materials which compose a thermo element. A thermoelectric material having a higher figure of merit ZT is more convenient, as it can carry out higher cooling power.

3. Performance tables

Table 1 Power Consumed table

S. No	Component name	Power rating
1	Peltier modules	12v 5A
2	Hot side exhaust fans	12v 2A
3	Cold side exhaust fans	12v 2A
4	Temperature control switches	12v 0.5A

Table 2 Tonnage of Refrigerator, power supply table

Temperature(Cold side)(°C)	Voltage(V)	Current (A)	Time (in minutes)
46.5	11.09	7.8	0
40	11.14	7.23	1
35	11.19	7.06	2
32	11.22	6.96	3
28	11.24	6.86	4
22	0	0	5

Conclusions

1) Thermoelectric refrigerator is fabricated by using two peltier cooling systems.
2) The maximum lowest temperature of the refrigerator is limited due to irreversibility in exhaust fans.
3) Thermoelectric cooling is beneficial only when there is direct contact refrigeration is required.
4) It is also concluded that thermoelectric refrigeration system can also be used for air conditioning with proper designs.
5) Higher cooling capacities when used in moving vehicles.

References

S.Stackhouse,L.Stixrude(2010),Theoretical Methods for calculating the Lattice thermal Conductivity of Minerals, Mineralogy & Geochemistry, Vol.71pp.253-269.

EnescuD, Virjoghe EO, (2014) A review on thermoelectric cooling parameters and performance, Renewable and Sustainable Energy Reviews,38:903-916.

J.Vian, D.Astrain,(2008) Development of a heat exchanger for the cold side of a thermoelectric module, Applied Thermal Engineering281514-1521.

S.Riffat, S.A.Omer, Xiaoli Ma, (2001), A novel thermoelectric refrigeration system employing heat pies and a phase change, Renewable energy 23(2001) 313-323

H.Julian Goldsmid (2014), Bismuth Telluride and its Alloys as Materials for Thermoelectric Generation, Materials 2014,7,2577-2592.

C.Hermes, J.Barbosa (2012) Thermodynamic comparison of peltier, stirling and vapour compression portable coolers, Applied Energy 91(2012)51-58.