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Design and Fabrication of Thermo Electric Refrigerator

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ABSTRACT

In the recent years, we have many problems such as energy crises and environment degradation due to increasing CO2 emissions on ozone layer depletion has become the primary concern to both developed and developing countries. Using thermo-electric module is going to be one of the most effective, clean and environment friendly system. The main advantage of the thermoelectric refrigerator is no need of any refrigerant and mechanical devices like compressor, prime mover, etc for its operation. Thermo electric refrigerator works on the principle of Peltier effect, when a direct current is passed between two electrically dissimilar materials heat is absorbed or liberated at the junction. The direction of the heat flow depends on the direction of applied electric current. The materials used for the thermo electric refrigerator are Silicon-germanium and its alloys. The main objective is to design and fabrication of thermo-electric refrigerator with an interior cooling volume of 0.0258m3

KEYWORDS: *Thermo electric module, Peltier effect*

I. INTRODUCTION

There are several methods which can be employed to facilitate the transfer of heat from the surface of the thermoelectric to the surrounding. Electrons can travel freely in the copper conductors but not so freely in the semiconductor. As the electrons leave the copper and enter the hot side of the p-type, they must fill a "hole" in order to move through the p-type. When the electrons fill a hole, they drop down to a lower energy level and release heat in the process. Then as the electrons move from the p-type into the copper conductor on the cold side, the electrons are bumped back to a higher energy level and absorb heat in the process the electrons move freely through the copper until they reach the cold side of the n-type semiconductor. When the electrons move into the n-type, they must bump up an energy level in order to move through the semiconductor. Heat is absorbed when this occurs. Finally, when the electrons leave the hot-side of the n-type, they can move freely in the copper. They drop down to a lower energy level and release heat in the process. To increase heat transport, several p type or n type thermoelectric (TE) components can be hooked up in parallel. The TE components can be put in series but the heat transport abilities are diminished because the interconnecting's between the semiconductors creates thermal shorting. The most efficient configuration is where a p and n TE component is put electrically in series but thermally in parallel. The device to the right is called a couple.

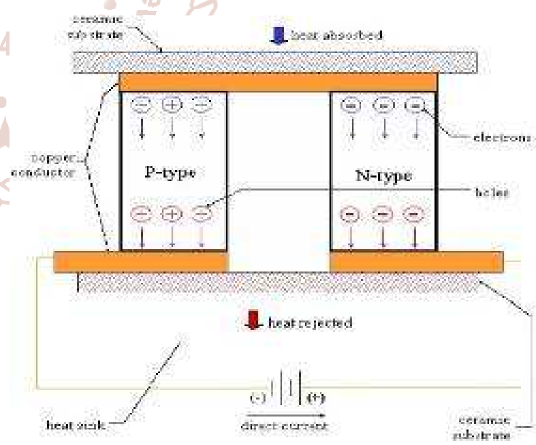

Fig 1: Thermoelectric couple

II. LITERATURE SURVEY

Manoj Kumar presented an experimental study of noval potential green refrigeration and air-conditioning technology. They are analysing the cause and effect of an existing air-condition system. Thermoelectric cooling provides a promising alternative R&AC technology due to their distinct advantages. The available literature shows that thermoelectric cooling systems are generally only around 5–15% as efficient compared to 40–60% achieved by the conventional compression cooling system [1].

Manoj and Walke conducted an experimental study of thermoelectric air cooling for cars. They are trying to overcome these demerits by replacing the existing HVAC system with newly emerging thermoelectric couple or cooler which works on Peltier and seebeck effect [2].

Yadav and Mehta presented combined experimental and theoretical study of thermoelectric materials and application. The present study develops an optimization design method for thermoelectric refrigerator. This device is fabricated by combining the standard n-channel and p-channel solid-state thermoelectric cooler with a two-element device inserted into each of the two channels to eliminate the solid-state thermal conductivity [3].

Maneewan conducted an experimental investigation of thermal comfort study of compact thermoelectric air conditioner. In this paper analyse the cooling performance of compact thermoelectric air-conditioner. TEC1-12708 type thermoelectric modules used for heating and cooling application [4].

Huang. B conducted an experimental study of design method of thermoelectric cooler. They are fabricated the thermoelectric cooler and analyse various considerations. The system simulation shows that there exists a cheapest heat sink for the design of a thermoelectric cooler. It is also shown that the system simulation coincides with experimental data of a thermoelectric cooler [5].

III. MATERIAL AND METHODOLOGY

Materials used in our work include Peltier module, aluminium foil, heat sink, cooling fan, plywood and temperature sensor.

Peltier Module

In this thermal energy could be absorbed at one junction and discharged at the other junction when an electric current flowed within the closed circuit. The most commonly used Peltier modules in the all applications are TEC1-12706, TEC1-12704, TEC1-12708. The Peltier unit in this fridge is TEC1-12706. This work on 12V DC and takes maximum current of 6amps at full load. The power rating of this unit is 92watts.

Fig 2: Peltier module

Specifications of Peltier module TEC1-12706

T_h (ºC)	27	50	Hot side temperature at environment: dry air, N_2
DT_{max} (ºC)	70	79	Temperature Difference between cold and hot side of the module when cooling capacity is zero at cold side
U_{max} (Voltage)	16.0	17.2	Voltage applied to the module at DT_{max}
I_{max} (amps)	6.1	6.1	DC current through the modules at DT_{max}
Q_{Cmax} (Watts)	61.4	66.7	Cooling capacity at cold side of the module under DT=0 ºC
AC resistance(ohms)	1.8~2.2	2.0~2.4	The module resistance is tested under AC

Cooling Fan

The fans used in this fridge works on 12V DC and draws 0.18amps. The power consumption of each fan is 2.16 watts.

Fig 3: Cooling fan

Heat Sink

Heat sink is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant, where it is dissipated away from the device, thereby allowing regulation of the device's temperature at optimal levels.

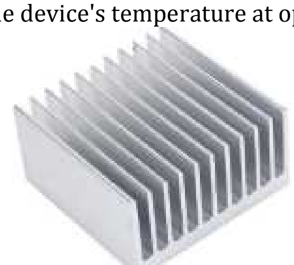

Fig 4: Heat sink

Aluminium foil

Aluminium foil is widely used for radiation shield (barrier and reflectivity), heat exchangers (heat conduction) and cable liners (barrier and electrical conductivity). Aluminium foil's heat conductive qualities make it a common accessory in hookah smoking: a sheet of perforated aluminium foil is frequently placed between the coal and the tobacco, allowing the tobacco to be heated without coming into direct contact with the burning coal.

Fig 5: Aluminium foil

Plywood
Plywood is a material manufactured from thin layers of wood veneer that are glued together with adjacent layers having their wood grain rotated up to 90 degrees to one another.

Fig 6: Plywood

Temperature sensor
The temperature sensor is a device which is used to sense the temperature of the refrigeration box and give us the accurate data about the rate of cooling of the box. It is an important device which is gives us the information about the cooling rate of the box and it also helps us to calculate the efficiency of the device i.e. thermoelectric refrigerator.

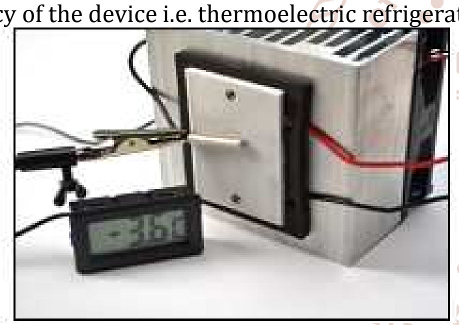

Fig 7: Temperature sensor

Designing of Refrigerator Body by SOLID WORKS 2016
Starting of SOLID WORKS 2016 is with a new name which will be displayed on the screen.

To start a new file in the part design workbench, choose file from the menu bar. The new dialog box is displayed. After accomplishment all the necessary cuttings and modifications of the refrigerator body, the ultimate model looks as shown in figure.

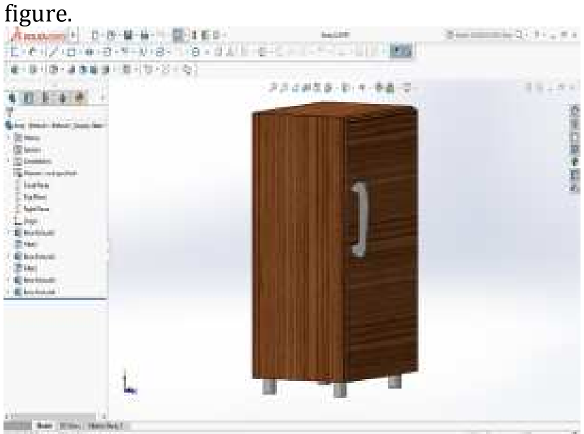

Fig 8: Refrigerator body

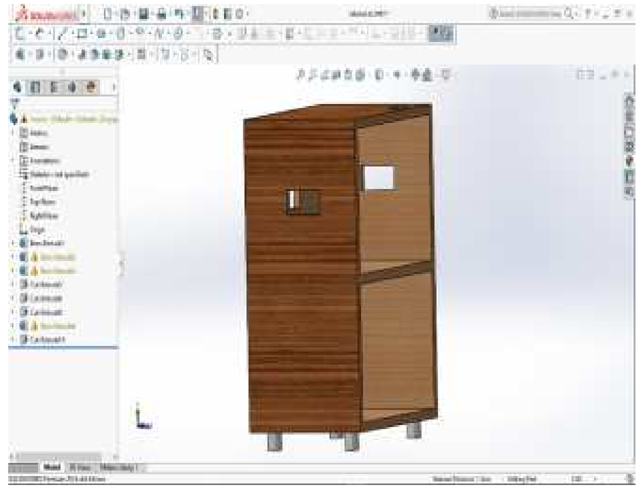

Fig 9: Refrigerator body interior

IV. FABRICATION
In this section we will discuss about the various design procedures that we have followed in the fabrication of the thermoelectric refrigerator.

Step 1: Making of refrigerator box
The first step is to make the refrigeration box. Firstly, we have taken the thermacol box for the purpose of refrigeration. After that the insulation is done on the both sides. On the outer side the insulation is done with the wooden ply of thickness 5mm and on the inner side the insulation is done with the aluminium sheet of thickness 1mm. The insulation is done to ensure that the box will remain cool properly and there is no loss of heat to the surroundings.

Fig 10: Plywood pieces before fabrication

Step 2: Cutting process
After the box has been made the back side of the box is cut in the proper dimensions to fit the fin-fan assembly in it.

Step 3: Drilling
Drilling is done on both the fins i.e. hot and cold side fins. The drilling is done to hold the both fins together tightly. The drilling is done by holding the both fins in a clamp tightly and after that the drilling is done on the drilling machine very precisely.

Fig 11: Refrigerator body after fabrication

Step 4: Mounting of thermoelectric module

Mounting of module must be done with utter most care. The surface of the fin, to be attached to the Peltier Module is wiped free off dirt and grease using alcohol or similar and thin film of thermally conductive silicon grease on the suitable surfaces. The thermoelectric module is then attached to the fin with the help of glue

Step 5: Tightening of screws

After the thermoelectric module is sandwiched between the fins both fins are tightened together with the help of screws in the holes which are drilled previously. The screws are tightened precisely, and the excess part of the screw is cut.

Step 6: Mounting of fin fan assembly

After the fins are tightened together the fans are attached to them and the whole assembly is mounted on the back side of the refrigeration box. The assembly is mounted in such a way that the cold side fin is inside the box and hot side fin is outside the box. The Peltier module is between the both fins.

Fig 12: Refrigerator body after fabrication with Peltier modules

Step 7: Selection of power supply

Now the circuit controller is mounted on the backside of box. The circuit controller is used as a power supply source. Both the fans and the Peltier module are attached to the circuit controller with the help of wires. The black wire is positive and red is negative. Here we have used the 12V dc power supply.

Fig 13: Power supply

V. WORKING

Circuit Diagram

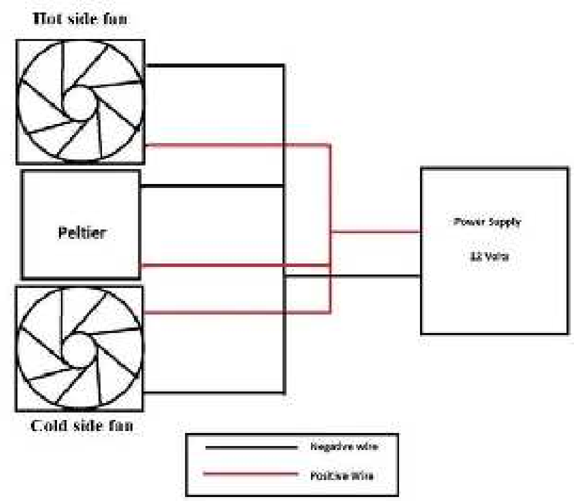

Fig 14: Circuit Diagram

In circuit diagram we can see that the Peltier is placed between the hot side fan and the cold side fan. Both the Peltier device and the fans are connected to the 12V power supply. Here the power supply is direct current (D.C.) because the Peltier device is a semiconductor device. The red wire is positive, and the black is negative. As the Peltier gets the power supply its one end gets hot and the other gets cold which is the basis of the working of our thermoelectric refrigerator. working the refrigerator is provided with a power supply of 12 volts and 10 amps DC current.

Working of TER

1. To start the refrigerator, the switch on the fridge is turned ON.
2. When the switch is turned on the Peltier devices and fan start functioning.
3. Cold sides of the four Peltier devices transfers the chilling effect to the evaporator.
4. Hot side of the Peltier are exposed to the atmosphere so that a fan will takes out the heat from hot side at faster rate.
5. The Peltier thermo electric device will be arranged in a box with proper insulation system and heat sink so that efficient cooling takes place at all the time.
6. To turn off the refrigerator, switch can be turned OFF.

VI. RESULTS AND DISCUSSION

COP of TEM (Thermo electric module)

Heat Absorption (Q_c) = $\alpha IT_C - 0.5I^2R - K_t (T_h - T_C)$
Heat Rejection (Q_h) = $\alpha IT_h + 0.5I^2R - K_t (T_h - T_C)$
Where α = Seeback Coefficient in VK^{-1}
I = Current in amps
R = electrical resistance of the TEM in Ω
K_t = thermal conductivity of TEM in $Wm^{-1}K^{-1}$
T_c = Cold side temperature in K^{-1}
T_h = Hot side temperature in K^{-1}

Coefficient of performance (COP) = $Q_c / Q_h - Q_c$
$\alpha = 53\ VK^{-1}$ I = 10 A R = 2.1 Ω
$K_t = 0.025\ Wm^{-1}K^{-1}$
$T_c = 10\ ^oC = 283\ ^oK$
$T_h = 53\ ^oC = 326\ ^oK$

Heat Absorption(Q_c) = $53*10*283 - 0.5(10)^2 * 2.1 - 0.025(326-283)$
= 149883.9 Joules
= 150 KJ

For 4 Peltier modules Q_c = 150*4
= 600 KJ

Heat Rejection (Q_h) = $53*10*326 + 0.5(10)^2 * 2.1 - 0.025(326-283)$
= 172883.9 Joules
= 173 KJ

For 4 Peltier modules Q_h = 173*4
= 692 KJ

Coefficient of performance= $Q_c / Q_h - Q_c$
= 600/692-600
= 6.52

COP of TER (Thermo electric refrigerator)
Outer dimensions
Length = 40cm
Breadth = 30cm
Height = 50cm

Inner dimensions
Length = 33cm
Breadth = 23cm
Height = 34cm

Volume of the fridge
Volume Outer = Length*Breadth*Height
= 40 * 30 * 50 = 60000 cm^3
= 0.06 m^3

Volume Inner = Length*Breadth*Height
= 33 * 23 * 34 = 25806 cm^3
= 0.0258 m^3

Let the mass of the water inside the refrigerator be M_w
Let Specific heat capacity of water at constant pressure be C_p
Mw = Volume of water in the refrigerator * Density of water at 300K

Mass of the water in the box be M_w = Volume of water in the box * Density of water at 300K
= $100 * 10^{-6} * 1000$ = 0.1 Kg

1. Input Power = Voltage*Current
= (12V * 9A) = 108 Watts

2. Initial Temperature = 305K

3. Final Temperature = 300.7K

4. Total amount of heat removed = Total cooling effect produced
= $M_w * C_p$ * (Change in temperature)
= 0.1 * 4.12 * 4.3
= 1.7716 KJ = 1771.6 J

5. Input Work = Input power * Time (in seconds)
= 108W * 60 seconds
= 6480 J

6. Coefficient of performance
= Refrigeration effect / Input work
= 1771.6/ 6480
= 0.27

After conducting tests on designed Thermoelectric refrigerator following conclusions are drawn. From the experimentation it is observed that in TER the refrigeration effect can be increased as compared to single thermo electric refrigerator system. Experimental results show that the coefficient of performance(COP) of Thermoelectric refrigeration system is found to be 0.27

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