JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Design And Development of Hybrid Thermoelectric Refrigerator

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Abstract : Thermoelectric refrigeration uses the Peltier effect to transfer heat from one side to the other side which causes one side to heat up and the other side to cool down to a very low temperature. The Peltier module which exhibits the Peltier effect is used in thermoelectric refrigerators and it performs the function of a heat pump by moving heat from one side to the other side, The Peltier module is the heart of the thermoelectric refrigerator. One of the main disadvantages of thermoelectric refrigerators is their low efficiency, in our project we attempt to solve this problem by incorporating a helical coil heat exchanger in the thermoelectric refrigeration system in order to increase the efficiency and achieve a higher coefficient of performance (C.O.P.).

IndexTerms **- Thermoelectric, Peltier effect, design, fabrication**

I. INTRODUCTION

Our project has a wide arrangement of device called TEC (Thermoelectric couple), where electrons are used to carry out the heat from the system. Thermoelectric refrigerators are composed of the so-called Peltier modules, whose most notable physical phenomena are: See beck, Peltier, Joule, Thompson. We generally use thermoelectric refrigeration system when cooling load on the system is less. TECs inherently have many advantages over the alternate types of refrigeration. TECs are solid-state, so they have no moving parts. Because they don't have any moving components, they're far more reliable than any other refrigeration technology now on the market. TECs are also small and silent. The goal is to create a device that can perform the same job without contaminating the environment and to minimise CO2, SO2 generation, which has a detrimental impact on our ecosystem. The increasing production of CO2 and SO2 has resulted in the following effects on global warming and ozone depletion. Instead of employing the vapour compression or vapour absorption cycles, the goal is to use thermoelectric effects to produce cooling. The goal is to create a device that can perform the same job without contaminating the environment, as well as to minimise CO2 and SO2 generation, which has an impact on our environment.

II. PROBLEM STATEMENT

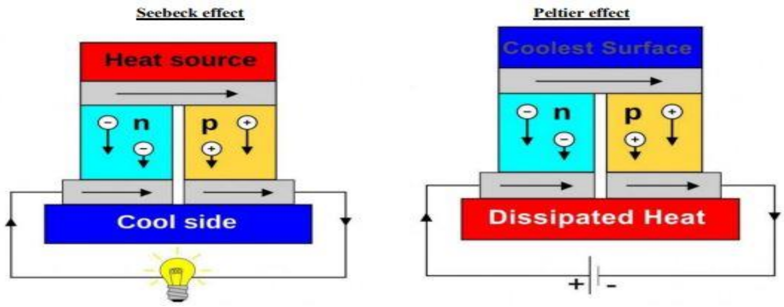
A refrigerant gas is used in these VCR systems to extract heat and provide cooling, the major drawback from these refrigerant gases is that they harm the environment by causing the depletion of the ozone layer. A Thermoelectric refrigerator which employs a Thermoelectric module solves the above-mentioned problems quite easily as it is a solidstate device that does not have moving parts or a refrigerant gas and can be moved from one place to another owing to its light weight and used immediately and also prevents the depletion of the ozone layer and presents itself as an ecofriendly alternative to the traditional refrigerators.

Proposed system of thermoelectric refrigeration

1. To use a heat pipe heat sink on the hot side of the Peltier module to cool it to get a greater temperature difference between the both sides of the Peltier module which results in an increased rate of cooling and sub zero temperatures on the cold side of the Peltier module.
2. To add a Thermosyphon system to the cold side of the Peltier module by using an Aluminium cooling block that is connected to a pump and coil.
3. A helical coil tube to be used in the Thermosyphon system.
4. Water to be used as the refrigerant and circulated in the helical coil with the help of a pump.
5. A fan is to be fixed on the top side of the refrigerator cabinet for circulation of air to enhance the heat transfer.

III. WORKING PRINCIPLE

Thermoelectric Effect The thermoelectric effect is the use of a thermocouple to convert temperature variations to electric voltage and vice versa. When the temperature on both sides of a thermoelectric device differs, a voltage is generated. Heat is transported from one side to the other when a voltage is applied to it, resulting in a temperature differential. An applied temperature gradient causes charge carriers in the material to diffuse from the hot side to the cold side at the atomic level. This phenomenon may be utilized to create power, measure temperature, and alter item temperatures. The applied voltage affects the direction of heating and cooling, hence thermoelectric devices can be employed as temperature controls. The phrase "thermoelectric effect" refers to three distinct phenomena: the Seebeck effect, the Peltier effect, and the Thomson effect. The Seebeck and Peltier effects are two sides of the same physical phenomenon. Lord Kelvin is credited with developing the Thomson effect, which is an extension of the Peltier– Seebeck concept



Objectives of project

1. To create a hybrid thermoelectric refrigerator that combines the traditional thermoelectric refrigeration system with a helical coil heat exchanger setup.

2. To achieve better performance and increase the efficiency of the traditional thermoelectric refrigerator and achieve higher coefficient of performance.

3. The refrigerator is powered by dc current we would like to keep the possibility of its portability intact as it has lot of potential in logistics department for medicine transportation, e commerce sector, food delivery etc

Components used

1. Copper Tube - A 21-gauge copper tube of 0.8mm wall thickness and outer diameter of 6.35mm, inner diameter 5.55mm was used to build the helical coil heat exchanger, a total of 8 meters length of the tube was used in making the helical coil.

2. Polystyrene box - Polystyrene box was used to make the refrigerator cabinet owing to its low cost and ease of access and availability also due to its superior insulation capability compared to other materials and the polystyrene material is lightweight, can be easily cut down to the desired dimensions and it is nontoxic in its inherent available form.

3. DC diaphragm pump - A diaphragm pump having a max power rating of 12 volts and 1 amp drawing 12 Watts power has been used in the project working model, the main reasons for using this exact pump is its compact size, efficiency, power, flow rate of 3 liters/min and the self-priming ability exhibited by the pump.

4. Switch Mode Power Supply - The switch mode power supply device was used to convert the A.C. current from the mains supply outlet to D.C. current as all the components used in this project required D.C. current to operate

5. Thermostat and Thermometer - The XH-W1219 is a microcontroller device which serves the function of a thermostat to maintain and control the temperature of the system, it is programmed to take input from the buttons provided and sets the temperature which is later displayed in the display, it also has a secondary display that displays the current temperature of the system by using the probe connected to it, this has resulted in the elimination of using a separate thermometer.

6. Fan - Two brushless D.C. fans were used in the working model of our project. A 12 volt 0.18 amp fan was used to blow air on the hot side of the heat sink and another fan of 12 volt 0.15 amps was used to circulate air inside of the refrigerator cabinet.

7. Heatsink - The hot side of the Peltier module was interfaced with an aluminum heatsink with the help of the thermal grease. Aluminum heatsink was used here due to its low cost, easy availability and due to its thermal properties, such as high thermal conductivity of 239 W/m-k and very low thermal resistance it is best suited to serve

8. Peltier Module - A Peltier Module having the specifications of 12 volts, 6 amps with max capacity 72 Watts was used in the construction of the working model of the project. The dimensions of the Peltier module are 40mm*40mm*4mm. The Peltier module acts as a heat pump and moves heat from one object to another object.

9. Refrigerant - Ethylene Glycol coolant concentrate available by the brand name Castrol of model radical was used as the refrigerant due to its low specific heat and high thermal conductivity and its low freezing point and high boiling point to effectively enable heat transfer, heat exchange between the Peltier module and the load through the copper coil, plastic pipe and water block assembly

IV. .METHODOLOGY

3D CAD model: Solid edge version 2022 was used to construct the individual components of the project model and then assembled together

Isometric view of CAD model

Top view of CAD model

Fabrication of Coil

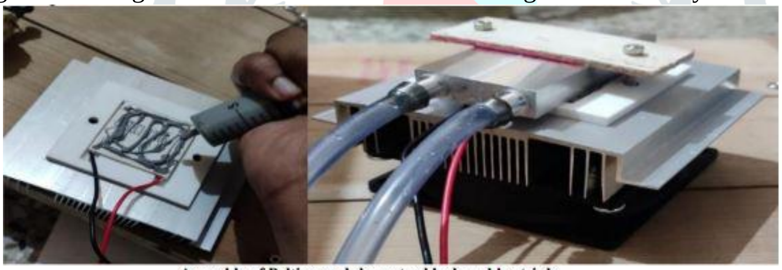
The Copper tube was wound onto a cylindrical object of 20cm outer diameter in order achieve the inner diameter of 20cm for the coil with 13 turns and height of 27.5cm was achieved by using 8 meter of copper tube with volume carrying capacity of 190ml.

Copper Coil Tube

Copper Coil tube placed in refrigerator cabinet

Assembly of Peltier module, water block and aluminum heatsink with fan

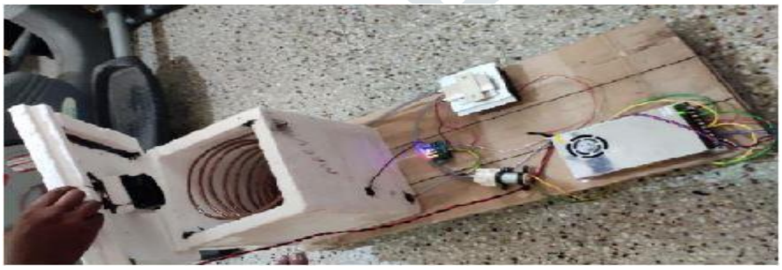
The Peltier module, water block, aluminum heatsink were assembled together with the help of screws and fastened together, thermal grease was used at the contact surfaces between these components to eliminate air gaps and increase thermal conductivity between them. An insulation gasket was placed around the Peltier module to prevent heat gain. A fan was fixed to the aluminum heatsink for dissipating heat coming from the Peltier module and cooling the heatsink by blowing air onto it.



Assembly of Peltier module, water block and heatsink

Electrical Connections, Connecting All Components and Filling Up Refrigerant.

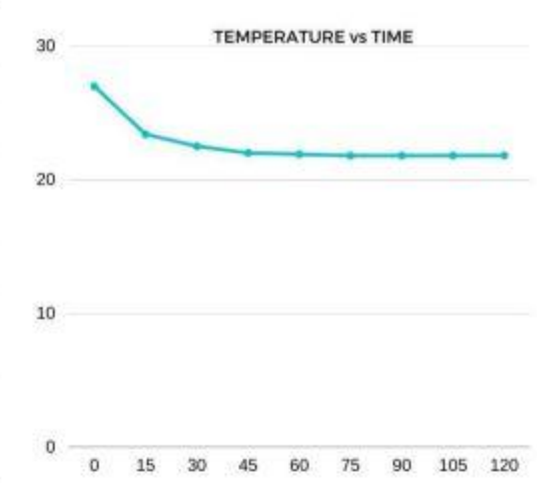
The Peltier module was connected to the Thermostat and the connections to the power supply were made to supply power to all the electronic components such as the Peltier module, brushless fans, diaphragm pump, the thermostat and thermometer. After connecting the components together, they were fixed onto a raised wooden board using screws. A hole was made in the wooden board to allow airflow to the heatsink



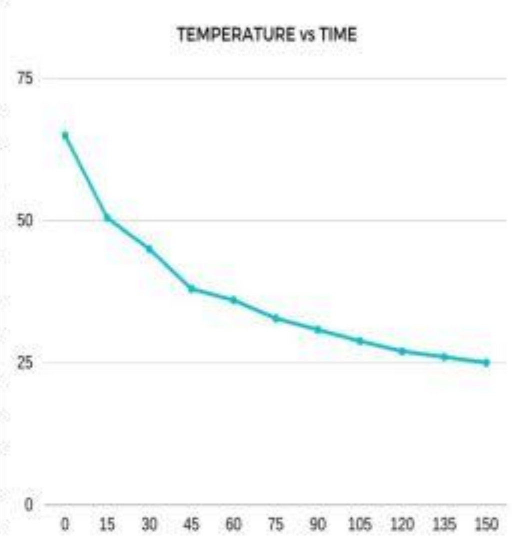
Performing The Experiment

1. The refrigerator was run for 2 hours without any load present and readings were taken for every 15 minutes, the readings were tabulated and the time vs temperature graph was plotted as follows
2. A glass jar filled with water was placed inside the refrigerator cabinet in the inner diameter area of the copper tube coil.
3. The initial temperature reading of the water was taken
4. The refrigerator was run for 2 hours with the load present and readings were taken for every 15 minutes, the readings were tabulated and the time vs temperature graph was plotted as follows
5. During the course of the operation the aluminum heatsink reached a temperature of 35.9 °C and the water block reached a temperature of 20 °C.

Sl no.	Time (min)	Temperature (°C)
1	0	27
2	15	23.4
3	30	22.5
4	45	22
5	60	21.9
6	75	21.8
7	90	21.8
8	105	21.8
9	120	21.8



Sl.No	Time (min) Temperature (°C)	Time (min) Temperature (°C)
1.	0	65
2.	15	50.5
3.	30	45
4.	45	38
5.	60	36
6.	75	32.8
7.	90	30.8
8.	105	28.8
9.	120	27
10.	135	26
11.	150	25



Formulae Used

Q = m * Cp * ΔT
Where, Q = Heat load, m = mass,
Cp = specific heat capacity,
ΔT = temperature difference Q cooling = Q / (time taken for cooling in seconds)
COP = Q cooling /W total
Where, COP = coefficient of performance,
Q cooling = Total heat removed per second,
W total = total power supplied

Calculations

Cooling load/heat load calculations
For water,
Q(water) = m * Cp(water) * ΔT
Mass, m = 0.5kg ; Specific heat capacity, Cp(water) = 4182 J/kg°C ; ΔT =14.5°C
Q(water) = 0.5 * 4.182 * (65-50.5)
Q(water) = 30319.5 J
For glass jar,
Q(glass jar) = m * Cp(glass) * ΔT
Q(glass jar) = 0.2 * 840 * (65-50.5)
Q(glass jar) = 2436 J
For copper tube coil,
Mass, m = 0.84 kg ; Cp(copper) = 389 J/kg°C ; ΔT =7°C
Q(copper tube coil) = 0.84 * 389 * (34-27)
Q(copper tube coil) = 2287.32
J For refrigerant,
Mass, m = 0.1635 kg ; Cp(ethylene glycol) = 2360 J/kg°C ; ΔT =7°C
Q(ethylene glycol) = 0.1635 * 2360 * (34-27)
Q(ethylene glycol) = 2701.02 J

For Water block, Mass, m = 0.1 kg ; Cp(Aluminium) = 900 J/kg°C ; ΔT =12°C Q(Waterblock) = 0.1 * 900 * (34-22) Q(Waterblock) = 1080 J
For the air in refrigerator cabinet,
Mass, m = 0.016038 kg ; Cp(Air) =1.005 J/kg°C ; ΔT =7°C
Q(Air) = 0.016038 * 1.005 * (34-27)
Q(Air) = 0.1123 J
Total Heat load, Q(Total) = Q(water) + Q(glass jar) + Q(copper tube coil) + Q(ethylene glycol) + Q(Waterblock) + Q(Air) Q(Total) = 30319.5 J + 2436 J + 2287.32 J + 2701.02 J + 1080 J + 0.1123 J
Q(Total) = 38823.95 J
Qcooling = 38823.95 J / 900 seconds
Qcooling = 43.1377 Watt Power supplied, in Watt
W(Total) = 12 + 72 + 2.16 + 1.8 = 87.96 Watt Coefficient of Performance,
(C.O.P) = Qcooling / W(Total) C.O.P = 43.1377 / 87.96
C.O.P = 0.49

V. RESULTS

Coefficient of Performance (C.O.P) of 0.49 was achieved with the power input of 87.96 Watt for the thermoelectric refrigerator with the implementation of the helical coil heat exchanger compared to the C.O.P. of 0.3 of a regular thermoelectric refrigerator. It has been noticed that there is increase in the C.O.P. by 0.19.

VI FUTURE SCOPE OF PROJECT

1. Owing to the D.C. current requirements of this refrigerator it can be used in different applications that require portability of refrigeration. The smaller and compact design of this refrigerator enables it to be used in places where space is restricted such as cars and other vehicles and small apartments.
2. Due to its portability, and compact lightweight design it can be retrofitted onto motorcycles, mopeds to carry and supply vaccines in rural areas.
3. Since there are no CFCs used in this refrigeration system it is not toxic or harmful to the environment and people and is safe to use without fear of the harmful gases leaking from it as it is sometimes in the case of vapour compression refrigerators.
4. The waste heat from the refrigerator system can be recovered easily as it is concentrated towards the Aluminium heatsink from hot side of the Peltier module which allows items to be heated on one side and items to be cooled on the other side. Alternately the waste heat can be reutilized to produce electricity with the help of a thermoelectric generator or the waste heat can be used to do useful work by interfacing a heat engine to the hotter heatsink

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