International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

Application of Peltier Effect in Producing Eco-friendly, Smart Refrigerators

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Abstract – *Peltier modules are basically electronic devices which are used for cooling other objects below ambient temperature as well as it is used for maintaining the objects at a certain temperature. Till now, according to various researches these modules do not produces hazardous substances and gas. So, this makes a good alternative to conventional refrigerator cooling systems. In this paper, we have presented few observations which we have made in order to understand the nature and working of peltier modules more deeply*.

***Key Words*: peltier modules, ambient, temperature, hazardous, conventional cooling.**

1. INTRODUCTION

In the recent years, we are facing many problems such as energy crises and environment degradation due to increasing CO2, HCFCs and CFCs emissions causing ozone layer depletion. It has become the primary concern to both developed and developing countries. As the conventional refrigeration systems consumes more electrical energy and release more hazardous gases such as CFCs which are of major environmental damage concern nowadays. Even coolants used are not eco-friendly and much more costly. In these type of refrigerators, there is a tendency of leakage of refrigerants which can lead to ineffective cooling, wastage of electric energy and polluting atmosphere. Thus, thermoelectric module is going to be one of the most effective, clean and environment friendly system.
Thermoelectric module works on the principle of Peltier effect i.e, when a direct current is passed between two electrically dissimilar materials, heat is absorbed or liberated at the junction due to which one side of the peltier plate gets cooled (the side inside the chamber)and the other side gets heated up(facing towards the atmosphere).The heat from the hotter side of the peltier plate is absorbed by using heatsink(or along with fan)and heat is dissipated into the atmosphere.

2. LITERATURE SURVEY

1. In thermoelectric module refrigerator mechanical parts such as, compressor, liquid coolant, condenser coil, evaporation coil and expansion valve are replaced by thermoelectric module. Ganesh S. Dhumal, P.A. Deshmukh, M. L. Kulkarni has done a thermoelectric module refrigerator and used solar panel along with rechargeable battery for providing power supply to the refrigerator[1]. The experimental setup of refrigerator had a capacity of 0.5liters insulated box and two peltier plates along with active heat sinks was used dissipate heat from the hotter surface of the peltier plate.

2. Palash Nakhate, Niraj Pawaskar, Purva Vatamwar , Saurabh Kalambe have worked on Eco-friendly Refrigerator built using peltier plates and active heat sinks[2]. Switching mode power supply (smps) of 12V was used to provide power supply to peltier plates for cooling the chamber and fans of active heat sink to dissipate heat from peltier plate to surrounding. Ambient temperature to store food in refrigerator is 3 to 5 °C (37 to 41 °F),with the help of the microcontroller a ambient temperature range of the cabin can be maintained using by turning off power supply to peltier when temperature is below 3°C.

3. Dong with the experimental setups compared the thermal performance of two different types of heat sinks, they are plate-fin and pin-fin heat sinks. Both the heat sinks are subjected to impinging flow for various flow rates and channel width. The pressure decreases and thermal resistance are calculated based on the volume averaging approach. Based on the obtained results pin-fin heat sink possess less thermal resistance than the plate-fin heat sink when dimensionless pumping power is minutes and the dimensionless length of heat sinks is large[3].

3. SEEBECK EFFECT

The German physicist Thomas Johann Seebeck discovered the Seebeck effectt in the year 1821. Seebeck conducted an experiment where he connected a copper wire and an iron wire forming a loop leading to two junctions, he heated at

the one junction and he kept the other junction at a lower temperature. Then he connected galvanometer in the loop to check the flow of electrons. After sometime, he observed certain deflections in the galvanometer, which proved that difference in temperatures at two different junctions resulted in the flow of an electrical energy in the loop.

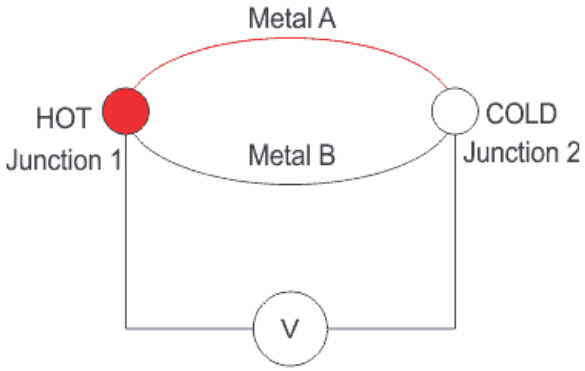

Fig -1: Schematic experimental setup of seebeck effect

Thus, Seebeck effect describes the production of an electromotive force (emf) and consequently an electric current in a loop of material consisting of at least two dissimilar conductors, when two junctions are maintained at different temperatures.

3.2 PELTIER EFFECT

Peltier effect is just the reverse of seebeck effect. This effect was discovered in 1834 by the French physicist Jean-Charles-Athanase Peltier. He had also conducted the experiment with the same setup i.e bismuth and copper wires forming two junctions connected in a loop, but instead of connecting galvanometer, he connected a battery in the loop and note that he didn't keep the junctions at different temperatures, like seebeck effect, in the beginning. Thus, he observed that after the passage of electric current in the loop, the junction which was kept hot according to seebeck effect became cold and viceversa. Thus, a reverse phenomenon was observed.

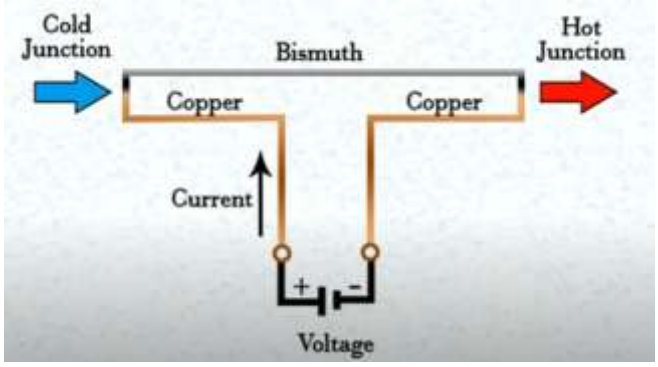

Fig -2: Schematic experimental setup of peltier effect

Thus, Peltier effect describes the cooling of one junction and the heating on the other junction when electric current is passed through the circuit of material consisting of two dissimilar conductors; the effect is even stronger in circuits containing dissimilar semiconductors.

The Peltier coefficient $\prod$ is defined as the coefficient of the thermal current **Q** to the electrical current **I** passing through loop, given by:

$$Q=\prod I \qquad [1]$$

The Peltier coefficient is related to the Seebeck coefficient(S) as:

$$\prod=S\,T \qquad [2]$$

Where T =temperature at the junction.

3.3 WORKING OF PELTIER MODULE

A peltier module consists of two unique semiconductors, one n-type and one p-type, which are used because they need to have different electron densities. The alternating p & n-type semiconductor pillars are placed thermally in parallel to each other and electrically in series and then joined with a thermally conducting plate on each side, usually ceramic removing the need for a separate insulator. When a voltage is applied to the free ends of the two semiconductors there is a flow of DC current across the junction of the semiconductors causing a temperature difference. As the electrons travels from P type material to N type material, the electrons hop to the higher energy state hence absorbing thermal energy (cold side). Then as the electrons travel from N type material to P type material, the electrons drop to the lower energy state and hence, dissipating thermal energy (hot side) to the surrounding environment. The higher is the rate of dissipation of heat, the cooler it gets inside the chamber (cold side of peltier plate) and hence increasing the efficiency of the cooling module proportionally.

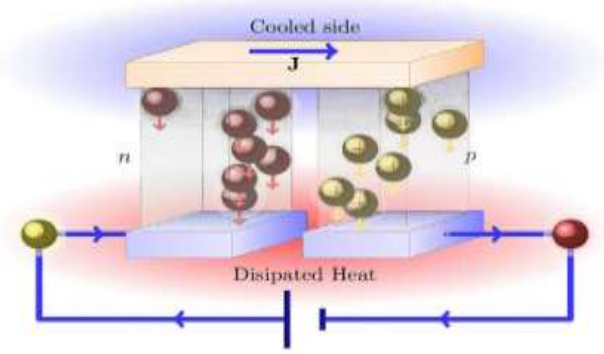

Fig -3: Working Principle of Thermoelectric module

4. BLOCK DIAGRAM

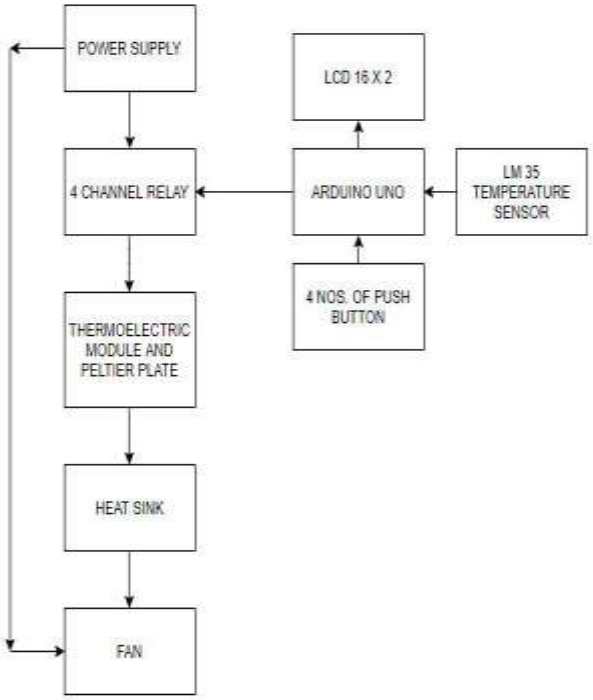

Fig -4: Schematic block diagram of the refrigerator

Power supply of 12V from smp's is given to the peltier plates through 4-channel relay for controlling supply to the peltier plates and 5V supply to the fans of heat sink. Peltier plate produces two different temperature that is, on one side of the peltier plates has low temperature and on the other side of the peltier plate has high temperature and both sides are referred as cooler side and hotter side respectively. At the hooter side of the peltier plate, active heat sink made up of aluminum is attached with the help of thermopaste to remove the heat from the cabin of the refrigerator. Similarly at the cooler side of peltier plate a passive heat sink is attached to distribute cool inside the cabin. We have used arduino uno which is a microcontroller to convert the thermoelectric module refrigerator a smart one. LM35 is an analog temperature sensor with the sensitivity of 10mV/°C and temperature reading from this is converted to digital value and displayed over a LCD 16X2 screen We have used 4 pushbuttons to maintain different temperature range inside the insulated refrigerator cabin.

5. PELTIER EFFECT BASED ON DIFFERENT EXPERIMENTAL SETUPS AND THERE RESULTS

We have conducted different experiments setups for peltier plate for checking it's better perform and to study its nature of cooling effect.

5.1 1st Experimental setup

In this experimental setup we have just placed only peltier plated and 12v power supply is provided to it from smps. The data is collected during this experimental setup and plotted the line graph with temperature variation at the cooler side versus the time taken to achieve it as shown in chart-1.Initially temperature was at room temperature, after providing power supply the cooler side started getting cold and temperature went up to 18 degree for first 25 seconds. Later due to lack of proper coolant or heatsink to absorb heat from the hotter side of peltier plated and due less thickness, temperature started to pass from hotter side to cooler side of peltier plate. So, temperature went on rising and after 1 minute temperature at cooler side was 32 degrees.

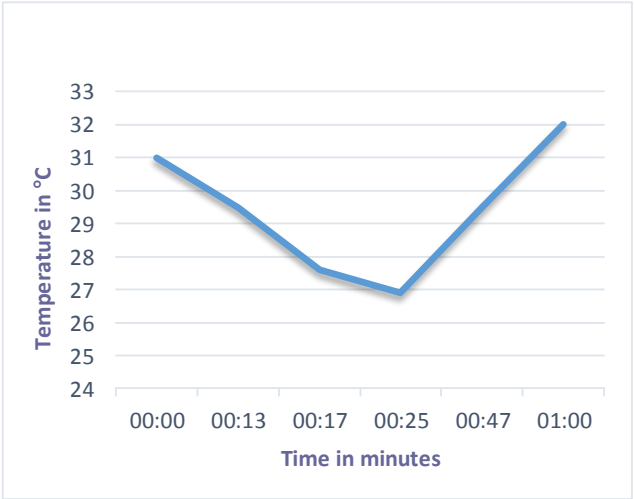

Chart -1: Peltier plate without heat sink

5.2 2nd Experimental setup

In this experiment setup we have used heat sink of small size of 36sqcm and attached it to hotter side of peltier plate with thermopaste. Initially when power supply was given to peltier plate, temperature at colder side of peltier plate was at room temperature of 31 degree Celsius. Later gradually temperature at the colder side peltier plate went on decreasing and lowest temperature achieved was 21.7 degree Celsius with in 1min and 50 seconds. Later due to problems as mentioned above, colder side of peltier started getting heated and by the end of 2 min 15 sec temperature at the colder side of peltier plate reached 35 degree Celsius. Even this setup was not effective for cooling the icabin.

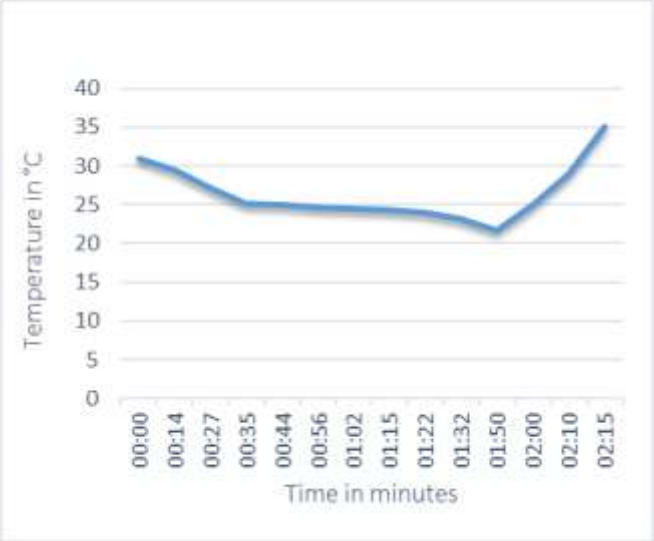

Chart -2: Peltier plate with small active heat sink

5.3 3rd Experimental setup

As the above experimental setup, here we used stationary water as coolant with passive heat sink of 36sqcm for achieving better results. The plot of line graph based on the temperature reading recorded during experiment setup with respect to time is show in chart-3. There was temperature of 31 degree Celsius present at the cold side of peltier plate before providing power supply to peltier plates. After providing power supply the temperature gradually went low when measured at the cold side of peltier plate. The minimum temperature recorded at the cold side of peltier plate was 18 degree Celsius after approximate of 3 minutes. Later when water got heated, once again temperature at the cold side of peltier plate went high. So, even this setup was not effective. We didn't use circulation water as coolant because that needed a motor to pump the water which is again wastage of power.

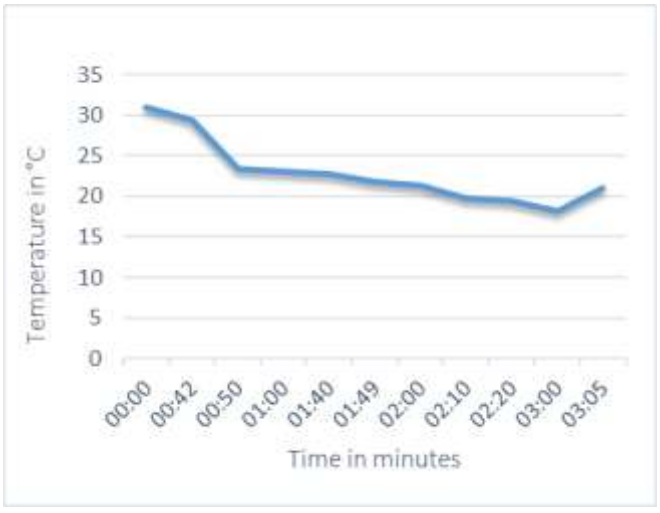

Chart-3: Peltier plate with heat sink and water coolant

5.4 4th Experimental setup

In this experimental setup we have used active heat sink of large size which is 81sqcm in area, large surface area for easy dissipation of heat to surrounding environment. Initially before providing power supply temperature at the cold side of peltier plate was 27 degree Celsius. Using the temperature reading obtained during experiment operation a plot of graph of temperature versus time taken to achieve that temperature is shown in chart-4. In this experimental setup the temperature went gradually low till 8 degree Celsius over period of 8 minutes and later it stayed constant at around 8 degrees Celsius itself.

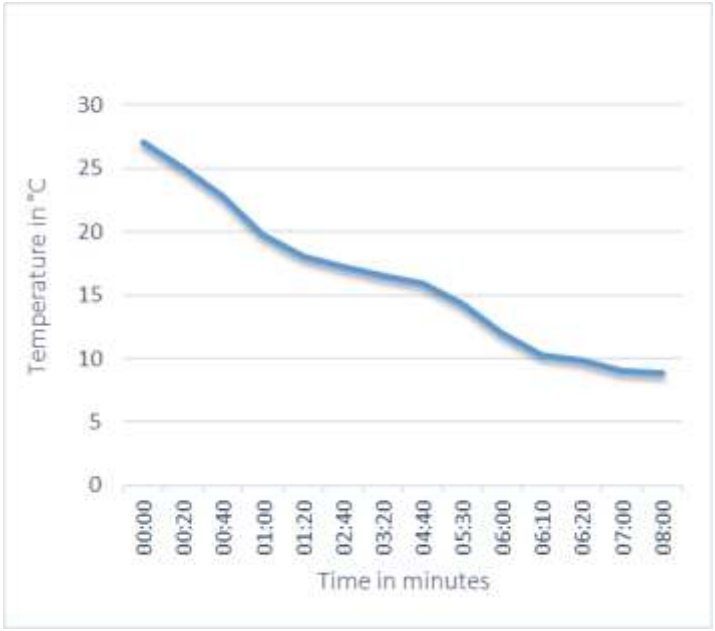

Chart -2: Peltier plate with large active heat sink

From all the different experimental results observation, 4th experimental setup was efficient and able to achieve lowest temperature among different experimental setups. So, for cooling insulated cabin we have used the 4th experimental setup.

6. OBSERVATION

After building a insulated cabin with the help of thermocol of size 0.20meter height, 0.15meter width and 0.12meter breath which is equivalent to 3.6liters cabin. Pasting aluminum sheet inside the cabin for equal distribution of temperature inside the cabin. Two peltier plates with active sink attached to the hotter side of peltier plate was placed outside the cabin to dissipate heat to surrounding and passive heat sink was placed inside the cabin to lower the cabin temperature.

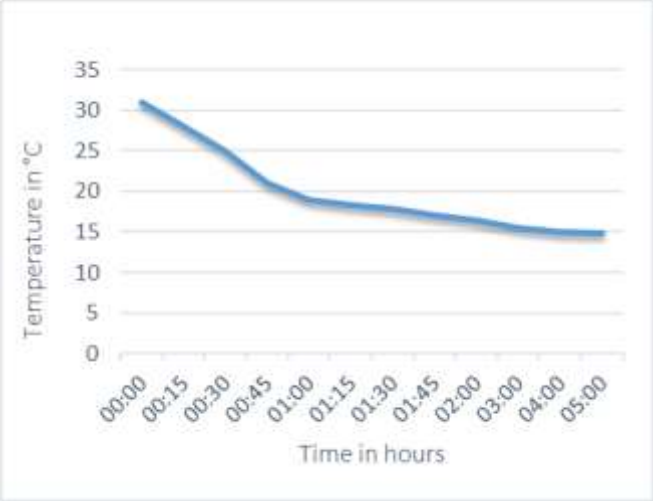

Chart -5: Insulated cabin temperature

7. FUTURE SCOPE

Peltier module based refrigerator has a clearer approach of working so it can work as a good alternative to conventional refrigeration. It can be integrated with solar cells thus can help in switching to renewable source of energy. It will be a much cheaper source of refrigeration. It can be very helpful in rural and remote areas where electricity supply is not reliable. It can be used in military and mobile ambulances to preserve medicines.

8. DRAWBACKS

1. This refrigerator provides limited cooling, so it's efficiency is lower to the traditional cooling devices.
2. We are not yet aware of the health hazard which it might cause.
3. Including high-end features can raise the price and complexity of the model.

9. CONCLUSIONS

This peltier refrigerator is more reliable than other portable refrigerators. It is cost efficient and ecofriendly which is the most wanted requirement of today's era. By controlling the temperature range of the cooling unit, it can be used in various sectors like for in the rural areas where dairy products need a lot of attention, near the coasts from where the marine edibles need to be transported to the market area, medical area for storing blood and pharmaceuticals. The efficiency of the refrigerator can be increased by increasing the number of peltier plate module which will eventually help in decreasing the temperature in less time. Number of peltier plate modules used can be calculated using the heat transfer formula.

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BIOGRAPHIES

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