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DESIGN AND FABRICATION OF PORTABLE THERMOELECTRIC REFRIGERATOR

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Abstract:

In this paper, design and fabricate a portable thermoelectric refrigerator is presented. The model casing and components are designed using CATIA Software and product is fabricated based on conventional manufacturing practices .This refrigerator consists of a thermoelectric module as cooling generator along with an insulated cabin, thermostat and charging unit. Thermoelectric elements perform the same cooling function as Freon-based vapor compression or absorption refrigerators. The design of the refrigeration is based on the principle of thermoelectric module (i.e., Peltier effect) to create a hot side and a cold side. The cold side of the thermoelectric module is used for refrigeration purposes. On the other hand, the heat from the hot side of the module is rejected to the surroundings with the help of heat sinks and fans. In this work, high efficiency is achieved for designed Portable Thermoelectric Refrigerator.

KEYWORDS: *Peltier Effect, Heat sink, Thermoelectric module, Refrigeration*.

1.0 Introduction

Refrigeration is a process of removal of heat from a space where it is unwanted and transferring the same to the surrounding environment where it makes little or no difference. Although a thermoelectric (TE) phenomenon was discovered more than 150 years ago, thermoelectric devices (TE coolers) have only been applied commercially during recent decades. For some time, commercial TECs have been developing in parallel with two mainstream directions of technical progress – electronics and photonics, particularly optoelectronics and laser techniques. Lately, a dramatic increase inthe application of TE solutions in optoelectronic devices has been observed, such as diode lasers, super luminescent diodes (SLD), various photo-detectors, diode pumped solid state lasers (DPSS), charge-coupled devices (CCDs), focal plane arrays (FPA) and others. The effect of heating or cooling at the junctions of two different conductors exposed to the current was named in honour of the French watchmaker Jean Peltier (1785–1845) who discovered it in 1834. It was found that if a current passes through the contacts of two dissimilar conductors in a circuit, a temperature differential appears between them. This briefly described phenomenon is the basis of thermoelectricity and is applied actively in the so-called thermoelectric cooling modules. Thermoelectric devices (thermoelectric modules) can convert electrical energy into a temperature gradient this phenomenon was discovered by Peltier in 1834.

Manoj Kumar Rawat[1] did an experimental study of comparing novel potential green refrigeration and air-conditioning technology. They are enumerating the cause and effect of air conditioning and came to the result that thermoelectric cooling provides a promising option for R&AC technology. They concluded that thermoelectric cooling is generally5-15% as efficient compared to 40-60% conventional compressor cooling.Kirti Singh[2] carried out the work on the development of portable cooler cum heater that utilizes solar energy with the use of thermoelectric module and photovoltaic module for generation of energy which could be further used for cooling and heating effect. They concluded that a thermoelectric cooler serves the purpose of pumping heat, and its misuse can heat up the CPU instead of cooling it down. Thermoelectric cooler needs to have a high heat capacity. S.Sreenath Reddy[3] the researchers carried out their work on design and fabrication of thermoelectric refrigerator using germanium and its alloys. They concluded that a thermoelectric refrigerator with interior Cooling volume of 0.0258 m3 is far better in comparison to conventional refrigerator.Vivek Vaidya[4] carried out the work on the experimentation of a thermoelectric refrigerator using Solar energy for cold storage application. They concluded that the refrigerator can be used only for light load to lower its temperature to a particular temperature. Further the system is unable to handle fluctuations in load. Meghali Gaikwad[5] carried out the work on the development of thermoelectric R&AC system. They compared the cost and efficiency of vapor compression, thermoelectric absorption refrigerators. They concluded that the vapor compression system was the most energy efficient as well it has the lowest operating and purchasing cost. Riffat & Qiu [6] compared the effectiveness of thermoelectric air conditioner to that of the vapor compression air conditioner and the absorption air conditioner. The other predecessors [7-12] have also contributed immensely to the design and fabrication of the thermoelectric refrigerator.

2.0 Methodology

2.1Design of Thermoelectric Refrigerator:

Thermoelectric cooling uses the Pettier effect to create a heat flux between the junctions of two different types of materials. A Peltier cooler, heater or thermoelectric heat pump is a solid - state active heat pump which transfers heat from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current.by applying low voltage DC power source to a TE module, Heat will be moved through the module from one side to other where is connected with long heat sink through DC fan the heat from the long heat sink is exhaust to atmosphere. where small heat sink is inserted to the casing where a small heat sink is attached with a DC fan to circulate the cooling effect from the small heat to the casing. All the connection of components is given to the AC to DC converter as per block diagram shown below the connection is given to the refrigerator. Where Peltier, DC Fan, Thermostat, etc. all this connected to the AC to DC Converter.

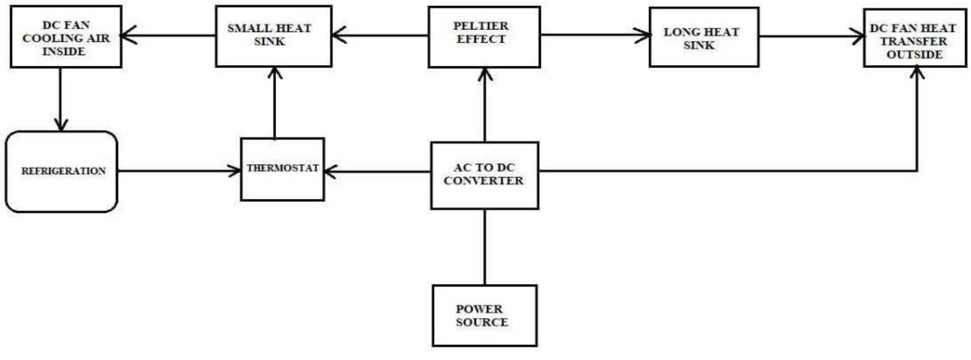

Fig.1: Block diagram for Thermoelectric process

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Table 1:Dimension of the Portable Box

Parts	Dimensions(mm)
Overall box length	550
Overall box width	450
Longer heat sink	120x70x40
Short heat sink	40x40x26
Ground clearance	20.2

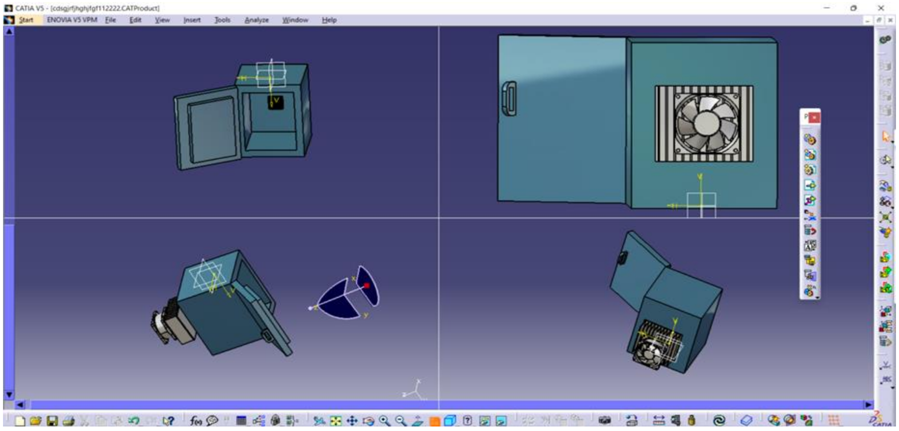

Fig. 2: Final assembled view in Catia

Figure 4: Final assembled view of experimental setup

2.2 Equations:

Every specific application where a thermoelectric cooler Module or refrigerator is required is characterized by a set of operation parameters, which dictate the necessity and Accurate selection of the optional thermoelectric cooler type of single-stage Thermoelectric cooler module.

2.2.1 Thermoelectric Cooler Module

The thermoelectric cooler module material chosen is Bismuth telluride. The properties of a 127 couple, 6A Bismuth Telluride module TEC1-127-06L are:

See beck coefficient (S) = 0.01229 V/k

Module thermal conductance (K) = 0.1815 W/k

Module resistance ® = 4Ω

2.2.2 Thermal Resistance Network

Thermal resistance network is conducted here for analysis. Since TEC generates Joule heat, it makes heat rejection, which is called QH, from TEC hot side larger than the heat Absorption, which is called QL, into TEC cold side. According to literatures, the general forms of heat Absorption and heat rejection are presented as bellow. Heat Transferred into the cold side when neglected theTemperature drop through the TEC is given by,

$QL = [SITc - \frac{1}{2} I^2R\text{-}k\ (Th\text{-}Tc)]$ (-) sign for heat rejection.

While the heat transferred out of the hot side into the heatSink is given by,

$QH = [SITc + \frac{1}{2} I^2R\text{-}k\ (Th\text{-}Tc)]$

See beck coefficient (S) and electrical resistance ® in ohms are dependentboth on the materials used within the TEC, but also on the geometry of thedevice, given by the number and dimensions of the individual N and P-type Semiconductor elements.

3.0 Results and Discussion

After measuring the temperature by radiation pyrometer, final temperature at the surface of module and the heat sink are as follow.

Temperature at hot side Th = 68˚ C

Temperature at cold side Tc = 17˚ C

So, Temperature difference can be considered as

$T = (Th - Tc) = (68\text{-}17) = 51^{\circ}C$

3.1 Efficiency of Single stage thermoelectric cooler

A non-dimensionless parameter called the efficiency is therefore used to measure the performance of a cooling machine. Efficiency is the ratio of the thermal output power and the electrical input power of the TEC. Efficiency can be calculated by dividing the amount of heat absorbed at the cold side to the input power Efficiency = QL/Energy supplied (W) Heat absorption is calculated as below.

$QL = -[SITc - \frac{1}{2} I^2R\text{-}k\ (Th\text{-}Tc)] = 58.21185$

From the first law of thermodynamics, the Energy supplied is:

Energy supplied, W = QH - QL

=SI (Th − Tc) + I^2R =103.13395 W

3.2 Efficiency

The efficiency is obtained by the following empirical equation.

Efficiency = QL/Energy supplied

=[SITc – ½ I^2R-k (Th-Tc)] /SI (Th − Tc) + I^2R

=58.21185/103.13395

Efficiency (η)=0.564432

A comparison of theoretical and experimental efficiency of the system with respect to time is given in Table 2.

Table 2: Comparison of Theoretical and Experimental efficiency (η)

Sno.	Time (min)	Theoretical efficiency (η)	Experimental efficiency (η)
1	30	0.5259	0.5240
2	60	0.5238	0.5221
3	120	0.5323	0.5318
4	180	0.5308	0.5308
5	240	0.5321	0.5283

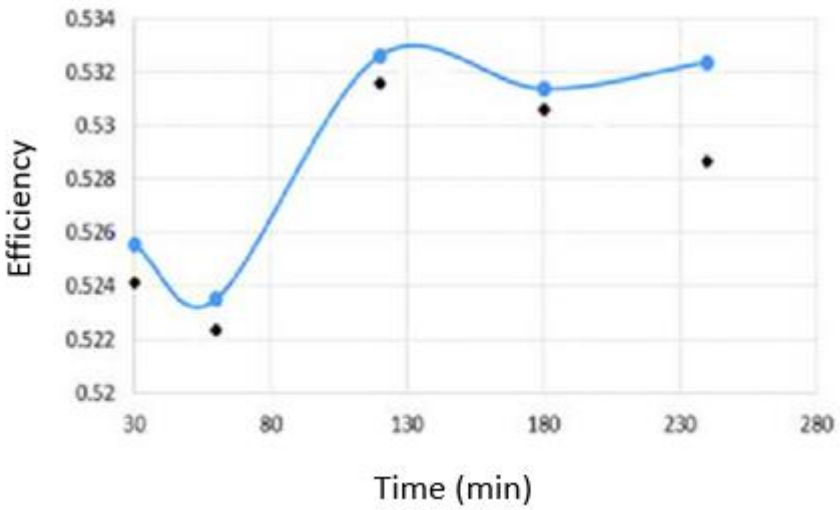

Figure 5: Variation of Efficiency with time

Here it is remarkable that the value of efficiency (η)is still lower than the expectation. Although the efficiency (η)of a TE module is lower than that of conventional VCR system, efforts have been made to develop thermoelectric domestic coolers to exploit the advantages associated with this solid-state energy conversion technology. Further improvement in the efficiency (η) may be possible through using multistage thermoelectric module, improving module contact resistance, thermal interfaces and heat exchanger. Among these possibilities use of multistage thermoelectric module is the simplest and presently available method. Due to the performance limits of thermoelectric materials, a single-stage thermoelectric cooler can only be operated over a small temperature range. If the temperature ratio between the heat sink and the cooled space is large, a single-stage thermoelectric cooler will lose its effectiveness. Thus, the application of two- or multi-stage combined thermoelectric refrigerator is an important method of improving the performance of thermoelectric refrigerator.

4.0 CONCLUSION

A portable mini refrigerator prototype was designed and built which can be used for personal cooling. It was constructed by using Thermocole with perfect dimensions. It is successful and the temperature readings were recorded. Cooling stabilizes within one hour once the switch is turned ON. It had been shown from testing results that the portable mini fridge is capable of cooling the can. All the components in the project had been tested individually and the results were found to be positive with and average efficiency (η) of 0.5274. This work has produced a good efficiency.

5.0 References

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