Design & Fabrication of Thermoelectric Air Cooling & Heating System by Forced Convection Method

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Abstract— The increase in demand for refrigeration globally in the field of air-conditioning, food preservation, medical services, vaccine storages, and for electronic components temperature control led to the production of more electricity and consequently an increase in the CO_2 concentration in the atmosphere which in turn leads to global warming and many climatic changes. Thermoelectric refrigeration is a new alternative because it can reduce the use of electricity to produce cooling effect and also meet today's energy challenges. Thermo electric refrigeration system uses peltier effect to produce hot and cold ends at each of its junctions. Cold end kept inside the cabinet to produce cooling effect inside the cabinet. Thermoelectric module can work either as a refrigeration system or a heat pump. This work presents an analysis of variation of temperature with respect to time for water cooled thermoelectric assembly. By dissipating large amount of heat from the hot side of module resulting in temperature drop in cold side of module.

Key words: Thermoelectric Air Cooling & Heating System, Forced Convection Method

I. Introduction

Due to the increasing demand for refrigeration in various fields led to production of more electricity and consequently more release of harmful gas like CO^2 all over the world which is a contributing factor of global warming on climate change. Thermoelectric refrigeration is a new alternative method. The thermoelectric modules are made of semiconductor materials electrically connected in series configuration and thermally in parallel to create cold and hot surfaces. Although they are less efficient than the vapour compression system, they are very light, low in cost, silent in operation, and are environmentally friendly.

The objectives of this project are to design and develop a working thermoelectric refrigerator that utilizes the Peltier effect to refrigerate and maintain a temperature between 5ºC to 25ºC. The design requirements are to cool the volume to a temperature within a short time and

Provide retention of at least next half an hour. And a thermosiphon cooling system is used for cooling the hot side of TEC module. It will be used in remote locations in the world where there is no grid electricity, and where electrical power supply is unreliable when a solar panel charger is added for battery charging.

II. Literature review

Review of a number of patented thermoelectric refrigerator designs, a photovoltaic-direct/indirect thermoelectric cooling system, and research studies from the literature are described in the following section. A simple design was proposed by Beitner in 1978 consisting of thermoelectric modules directly powered by an external DC source and an external thermal sink to dissipate heat to ambient by using natural convection cooling. Reed and Hatcher in 1982 proposed an effective way to increase the heat dissipating capability at the hot end of thermoelectric modules by using the cooling fan. Park et al. in 1996 introduced the new design of thermoelectric refrigerator by combining the benefits of super insulation materials with thermoelectric system and phase change materials to provide an environmentally benign system that was energy efficient and could maintain relatively uniform temperature for the extended periods of time with relatively low electrical power requirements. Gillery & Tex in 1999 proposed the design of a thermoelectric refrigerator by employing evaporating/condensing heat exchanger to improve heat dissipation at hot end of thermoelectric modules.

III. Components used

A. Thermoelectric Module

The 127 couples, 40 mm × 40 mm size single stage module is made of selected high performance ingot to achieve superior cooling performance and greater T up to 70 °C, designed for superior cooling and heating up to 100 ºC requirement. When coupled with an appropriate heat sink and power source, TEC1 Peltier Modules are suitable for the following applications.

B. Heat Sink

A heat sink is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium. Size 120x60x40mm.

C. DC Cooling Fan

2 set of 12v DC supply fan is used at the back side of heat sink. This will dissipate heat from sink. 3*3 inch Brushless Fan. Generally used in system, panel boxes etc. to keep the system cool. Specifications. Size: 3 × 3-inch (80 x 80 x 25mm); DC: 12V 0.20A. Speed: 3000 RPM; Blades: 7 blade cooling fan. Very low noise; Material: hard plastic. Color: black. Image shown is a representation only.

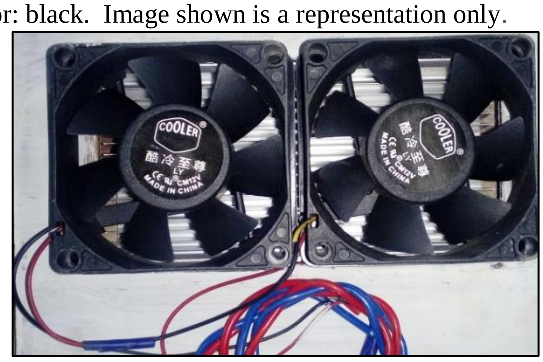

Fig 1 DC Cooling Fan

D. AC Fan

220V Ac fan of size 120x120x28mm used to extract heat from hot side of TEC. This will speed up the heat dissipation.

The AC cooling fan has become an essential component in nearly all modern electronics products. These fans supply the apparatus with cool air and create efficient air flow over the device so that it may operate correctly and at its full ability. Computer and electronics AC fans function in the same capacity as any regular household fan. The main purpose of these fans is to ensure that acceptable temperatures are maintained in an electronic device. The blades spin at different rates proportionately to the required amount of cooling. Together the device and fan

Fig. 2: AC Fan

E. AC-DC Convertor

We were using 3 TEC of each with 6amp, so we adopt a AC-DC convertor of 12V 40A with multi output.

Fig. 3: AC-DC Convertor

F. Cooling & Heating Cabin

Heating and cooling cabin with size of 30x60x60cm of each were designed Plywood used as cabin

Fig. 4: Cooling & Heating Cabin

G. Air Flow Duct

To avoid heat loss to the walls here we used thermacoal as heat insulator.

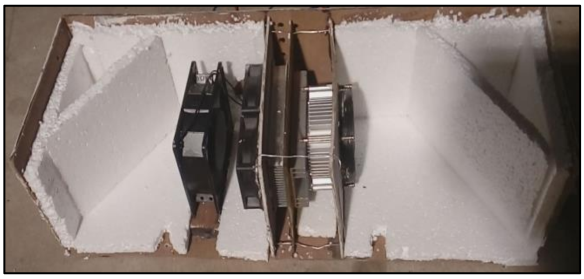

Fig. 5: Air Flow Duct

IV. EXPERIMENTAL ANALYSIS

A. Cooling Load Calculation

The amount of heat removed or the cooling power was determined before selection of the TEC. Qc which is the amount of heat absorbed was calculated using the equation

$$(Qc = m\, Cp\Delta T)$$

Mass flow rate (m) of air is the product of density of air (p) and volume flow rate (Q). Density of air at 30 °C was taken as1.164 kg / m3. Q was obtained by multiplying velocity of air pass through the rectangular duct of heat sinks and the cross section area of a heat sink. It is denoted by the equation (Q =V × A). Velocity of the air passing through the duct was measured using an anemometer and resulted in a reading of5m /s. Cross sectional area of the rectangular duct (W ×H) was calculated as 0.0054128m2 and the volume flow rate was 0.02706m3 / s. Specific heat of air (C) at 30 °C was taken as1007 J / kgK.

Sl. no	Time min	Cooling cabin Temperature ^{0}C
1	0	33.2
2	5	31.4
3	10	30.8
4	15	29.2
5	20	28.0
6	25	27.4
7	30	26.9
8	35	26.6
9	40	26.4
10	45	26.4

Table 1: Temperature Variance – Cooling Process

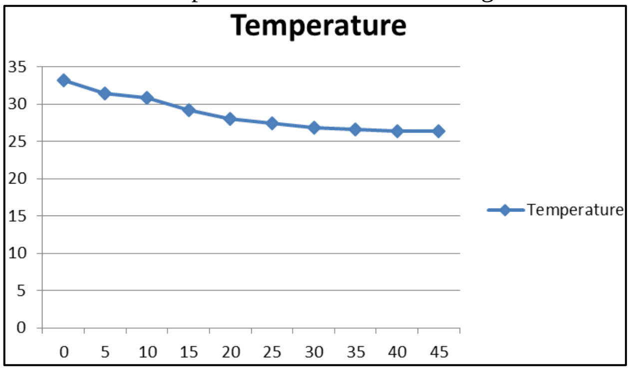

Fig. 6: Time Vs Cooling Temperature

All calculations used in the project, related to cooling load, selection of heat sinks, selection of fans, pressure drop calculations, surface area needed to cool the air etc. are mentioned below.

Qc the amount heat load to be absorbed by the cold junction has to be calculated before the selection of TECs.

$$Q_c = mC_p\Delta T$$

m = Mass of air Kg/s
C_p= Specific Heat of air in KJ/kgK
ΔT= Temperature difference in K

$$m = P\dot{q}$$

P = Specific weight = 1.164 Kg/m^3 (at 30^0C)
$\dot{q}$= V x A= Velocity x Area
Area = 0.1 x 0.06
= 0.006 m^2

$$q = 2.5 \times 0.006 = 0.015\ m^3/s$$

$$m = 1.164 \times 0.015 = 0.01746\frac{kg}{s}$$

$$\Delta T = 33.2 - 26.4 = 6.8\ K$$

$$Q_c = 0.01746 \times 1007 \times 6.8$$

$$Q_c = 119.5\ KJ/s$$

Q_h was calculated by adding the electrical power input and the cooling load.

$$Q_h = Q_c + P_e$$

P_e= 3 x 57.4= 172.2KJ/s
Coefficient of Performance

$$COP = \frac{Q_c}{P_e}$$

$$COP = \frac{119.5}{172.2} = 0.69$$

B. Heat Load Calculation

The amount of heat removed or the cooling power was determined before selection of the TEC. Qc which is the amount of heat absorbed was calculated using the equation

(Qh = m CpΔT)

Mass flow rate (m) of air is the product of density of air (p) and volume flow rate (Q). Density of air at 30 °C was taken as1.164 kg / m3. Q was obtained by multiplying velocity of air pass through the rectangular duct of heat sinks and the cross section area of a heat sink. It is denoted by the equation (Q =V × A). Velocity of the air passing through the duct was measured using an anemometer and resulted in a reading of5m /s. Cross sectional area of the rectangular duct (W ×H) was calculated as 0.0054128m2 and the volume flow rate was 0.02706m3 / s. Specific heat of air (C) at 30 °C was taken as1007 J / kgK

Sl. no	Time Min	Heating cabin Temperature ^{0}C
1	0	33.4
2	5	35.4
3	10	39.5
4	15	43.5
5	20	44.8
6	25	47.4
7	30	49.6
8	35	51.8
9	40	52.3
10	45	52.3

Table 2: Temperature Variance: Heating Process

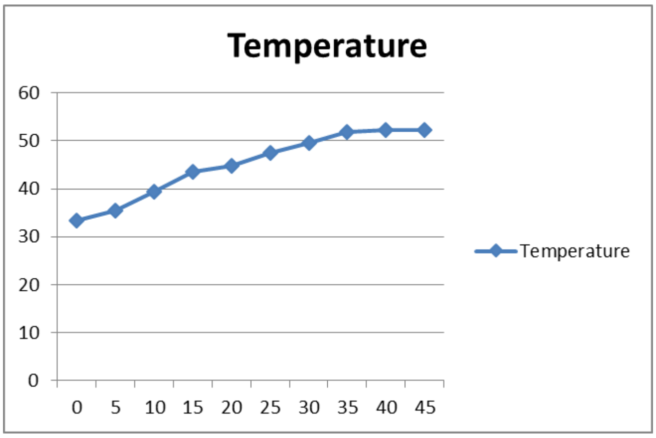

Fig. 7: Time vs Heating Temperature

All calculations used in the project, related to cooling load, selection of heat sinks, selection of fans, pressure drop calculations, surface area needed to cool the air etc. are mentioned below

Qc the amount heat load to be absorbed by the cold junction has to be calculated before the selection of TECs.

$$Q_c = mC_p\Delta T$$

m = Mass of air Kg/s
C_p= Specific Heat of air in KJ/kgK
ΔT= Temperature difference in K

$$m = P\dot{q}$$

P = Specific weight = 1.164 Kg/m^3(at 30^0C)
$\dot{q}$= V x A= Velocity x Area
Area = 0.1 x 0.06
= 0.006 m^2

$$q = 2.5 \times 0.006 = 0.015\ m^3/s$$

$$m = 1.164 \times 0.015 = 0.01746\frac{kg}{s}$$

$$\Delta T = 52.3 - 33.2 = 19.1K$$

$$Q_c = 0.01746 \times 1007 \times 19.1$$

$$Q_c = 335.8\ KJ/s$$

Q_h Was calculated by adding the electrical power input and the cooling load.

$$Q_h = Q_c + P_e$$

P_e= 3 x 57.4= 172.2KJ/s
Coefficient of Performance

$$COP = \frac{Q_c}{P_e}$$

$$COP = \frac{335.8}{172.2} = 1.95$$

V. CONCLUSION

A Thermoelectric Air cooling & heating system was designed and built which can be used for personal cooling & heating. Four TECs were used for achieving the cooling with a DC power supply through external power supply (dimmer stat). It had been shown from testing results that the cooling system is capable of cooling & heating the air when re circulating the air with the help of blower. TEC cooling designed was able to cool an ambient air temperature from 33.2°C to 26.4°C. Cooling stabilizes within ten minutes once the blower is turned ON (with a velocity of 2.5 m/s). The system can attain a temperature difference of set target which was 6°C. TEC designed was able to heat an ambient air temperature from33.5°C to 52.3°C. . With a single TEC, one hot side and a cold side heat sink a smaller personal TEC cooler which gives comfort can be fabricated and can be installed on roof for individual cooling by changing the airflow and some mechanical or electronics section modification, the TEC air cooling for car can be used for heating applications too.

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