STUDY OF THERMOELECTRIC COOLER

Al-rubaye, A.T., Mousa, M.G., Hegazi, A.A.
Department of Mechanical power, Faculty of Engineering, Mansoura University, Egypt.

Abstract— hermal performance of thermoelectric cooler is investigated experimentally. Thermoelectric cooling system is applied to many of engineering applications, the experimental test loop is deranged and providing under different operating condition. The effect of operating Parameters such as the voltage applied and air velocity on the performance of TEC., Experiments are Performed for applied voltage from 3 to 12 volts. And air velocity from 0.0 to 12m/s. The Experimental results showed that the minimum power consumption and maximum coefficient of performance occurs at lower values of the voltage applied.

Keywords— Thermoelectric cooler, COP, Natural convection, Forced convection.

1 INTRODUCTION

THERMOELECTRIC cooling, commonly referred to as cooling technology using thermoelectric coolers (TECs), has advantages of high reliability, no mechanical moving parts, compact in size and light in weight, and no working fluid. In summation, it has advantages that it can be powered by direct current (DC) electricity sources, such as photovoltaic (PV) cells, fuel cells and car DC electric sources. The primary disadvantages of thermo-electric cooling are the high cost and low energy efficiency, which has limited its application to cases where system cost and energy efficiency are less important than energy availability, system reliability and quiet operation environment.. Though thermoelectric cooling effect was discovered in the 19th century, it hadn't come to rapid development until 1950 when the basic science of thermoelectric materials became well established [1].

Recently, Liu et al. [2] performed a liquid-like behavior of copper ions around a crystalline sub lattice of Se in Cu2-xSe by The thermal conductivity which enables high ZT in this simple semiconductor. The outcomes indicate a novel scheme and management for high-efficiency thermo-electric materials by exploring systems where there exists a crystalline sub lattice for electronic conduction surrounded by liquid-like ions.

Chua et al. [3] studied the relationship between temperature and entropy. The entropy density was used to explain the capacity of thermo-electric cooling and thermo-electric heat generation.

Yang and Chen [4] analyzed the cooling capacity of one- and two-stage thermo-electric micro coolers without considering the Thomson effect and showed that the techniques of integrated circuit and micro electromechanical manufacturing are two primary skills for thermo-electric cooling development.

Ni et al [5] ran out an experimental subject of a thermoelectric conversion unit consisting of commercially available TEMs incorporated in a parallel plate heat exchanger.

Izam et al [6] studied the experimental a thermoelectric generator observed in the higher temperature raised a timeless constant temperature source (heat added), the less power abroad and shows the measured decrease in the current less resistance and thermal losses

Adeyanju et al. [7] carried out a theoretical and experimental analysis of a thermoelectric beverage chiller. The comparison was also formed between the thermo-electric beverage chiller's cooling time with cooking times obtained from the freezer space and cold space of a household refrigerator. The result establishes that for the refrigerator, freezer space, the temperature of the water decreased linearly with increasing time and for thermo-electric beverage chiller the temperature of the water decreased exponentially with increasing time.

Wahab et al. [8] Designed and developed an affordable thermo-electric refrigerator powered by solar cells generated DC voltage for the desert people living in Oman where electricity is not usable. In the study, the researchers used 10 nos. Of thermoelectric module in design of refrigerator. The finned surface (heat sink) was utilized to enhance and increase the charge per unit of heat transfer from the hot surface of the thermo-electric module. Cooling fan was used to eliminate the high temperature from the hot side of the module to ambient surroundings. The observational data accumulated from running one thermo-electric module indicate that it is possible to achieve temperature differences up to 26.60C at current 2.5 A and voltage 3.7 V. The coefficient of performance of the refrigerator was calculated and found to be approximately 0.16. An observational work on cooling performance of a developed combined Solar Thermo-electric- Adsorption cooling system has been taken out by Abdullah et al.

Min et al. [9] developed a number of prototype thermoelectric domestic-refrigerators with different heat exchanger combination and evaluated their cooling performances in

- *Ahmed Thabit Al_rubaye of Department of Mechanical power, Faculty of Engineering, Mansoura University, Egypt. and Department Mechanics of Faculty of Engineering Al-Qadisiyah University, Qadisiyah, Iraq. Corresponding Author: Ahmed Thabit Al_rubaye: Email: eng.ahmedalrubaye@gmail.com*
- *Prof and head of Department of Mechanical power, Faculty of Engineering, Mansoura University, Egypt. E-mail: mgmousa@mans.edu.eg*
- *Dr.Eng.* Hegazi, A.A *of Department of Mechanical power, Faculty of Engineering, Mansoura University, Egypt. E-mail: ahmedabd_elsallam@ mans.edu.eg*

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terms of the COP, heat pumping capacity, cooling down rate and temperature stability. The COP of a thermoelectric refrigerator is found to be 0.3-0.5 for a typical operating temperature of 5 C with ambient at 25 C. The potential improvement in the cooling performance of a thermo-electric refrigerator is also investigated employing a naturalistic model, with observational data obtained from this study. The outcomes indicate that an increment in its COP is possible through improvements in module contact resistances, thermal interfaces and the effectiveness of heat exchangers.
In the design of the present work are studied experimentally the effect of applied voltage and air velocity on the carrying out of TEC.

2. EXPERIMENTAL SETUP

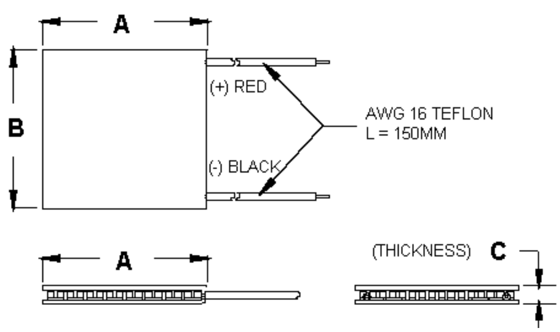
2.1 Thermoelectric Cooler (TEC)

The photo of the experimental setup is shown in Fig. (1).

The specifications of the experimental components of the main unit thermoelectric cooler (TEC1-12706) are shown in Table (1)

Table (1) operating specifications of TEC1-12706 [10].

	Min	Max
Hot Side Temperature (oC)	25	50
Qmax (Watts)	50	57
Delta Tmax (oC)	66	75
Imax (Amp.)	6.4	6.4
Vmax (Volt)	14.4	16.4
Module Resistance (Ohm)	1.98	2.30



The Dimension of TEC

A	B	C
40mm	40mm	3.9mm

In electronic systems, a heat sink is a passive heat exchanger that cools a device by dissipating heat into the surrounding medium. In computers, heat sinks are used to cool central processing units or graphics processors. Heat sinks are used with high-power semiconductor devices such as power transistors and optoelectronics such as lasers and light emitting diodes (LEDs), where the heat dissipation ability of the basic device is insufficient to moderate its temperature. A heat sink is designed to maximize its surface area in contact with the cooling medium surrounding it, such as the air. Air velocity, choice of material, protrusion design and surface treatment are factors that affect the performance of a heat sink. Heat sink attachment methods and thermal interface materials also affect the die temperature of the integrated circuit. Thermal adhesive or thermal grease improves the heat sink's performance by filling air gaps between the heat sink and the heat spreader on the device. On The experiment use installation of a thermal solution on the absorbent side of the heat in the unit TEC and the side that loses heat. Specifications of fan and heat sink are shown in Table 2.

Table (2) Specifications of Fan and Heat Sink [11]

Cooler dimension	83 x 80 x 77 mm
Heat sink material	Aluminium
Weight	388 g
Fan dimension	80 x 80 x 25 mm
Fan speed	3000 RPM
Fan airflow	38.08 CFM (64.54 m^3/h)
Fan air pressure	3.50 mm
Current rating	0.17A
Voltage rating	DC12V

Use Thermal grease (also called thermal gel, thermal compound, thermal paste, heat paste, heat sink paste, thermal interface material, grey goo, or heat sink compound) is a kind of thermally conductive (but usually electrically insulating) adhesive, which is commonly used as an interface between heat sinks and heat sources (e.g., high-power semiconductor devices). The grease gives a mechanical strength of the bond between the heat sink and heat source, but more importantly, it eliminates air (which is a thermal insulator) from the interface area.

Use variable power supply unit uses VDC, 3 to 12 Volt, with maximum current (20A) to supply unit TEC by source voltage and current variable and on both sides of the fan 12V fixed voltage.

2.2 Temperature measurement device

Sensor type lm35 are used to measure hot and cold Side Connected with processor type Arduino Shared data with the Lab VIEW Temperature, program in Computer to record data.

3 EXPERIMENTAL PROCEDURE

In figures (1) and (2) shows to setup part, installation the heat sinks on two side of thermoelectric Cooler (TEC) and connects ends of wires for fans heat sinks and TEC to the power DC, then installation sensors temperature on the surface of the hot side and cold side.

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Initially reset by the operating temperature readings and recording the first reading of the heat which is same with the environment.

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- Case 1: adjust the voltage variable power supply on the reading of power 3to12-volt (1) shown in fig. (3.2), the closed of hot side and open cold side fan startup and recording readings of temperature (4,6,7) and current (5), then to the time of ten minutes, that Enough time to stable.
- Case2: reset readings of new and re-use the same read power voltage but is running hot side fan heat sink and the closure of the fan mounted on the cold side heat sink, then record temperature readings and the read of the current user use the time for ten minutes.
- Case3: repeat readings reset using the same source power voltage but are running the vehicle fan on hot side heat sink vehicle fan on cold side heat sink, then record temperature readings and current use, time of ten minutes.
- Case4: repeat readings reset using the same source power voltage but shut down the vehicle fan on hot side heat sink vehicle fan on cold side heat sink, then record temperature readings and current use, time of ten minutesThe experimental work divided into four cases (shown in Table (3))

Table (3) experimental work cases

Symbol fan case	Case state fan
Case1	Fan side hot off - Fan side cold on
Case2	Fan side hot on - Fan side cold off
Case3	Fan side hot on - Fan side cold on
Case4	Fan side hot off - Fan side cold off

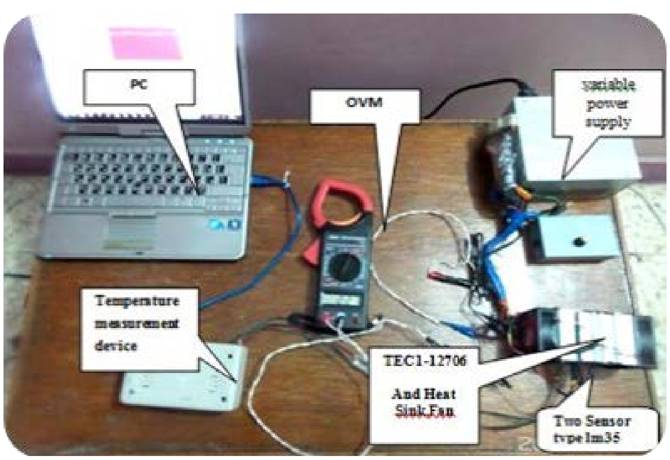

Fig. (1) Photo of the experimental setup

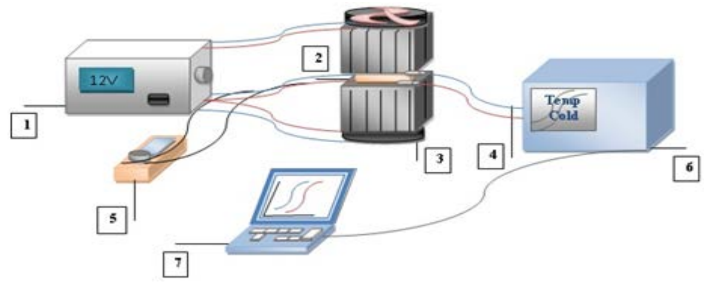

Fig. (2) Experimental set up

1-Power voltages supplied
2-TEC Thermoelectric
3-Heat sink and fan
4-Temperature sensors
5-AVO meter
6- Temperature recording device
7-PC Computer

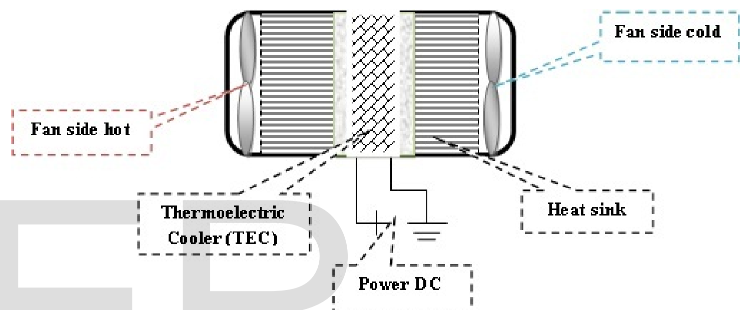

Fig. (3) Schematic diagram of the power supply operation

4 DATA REDUCTION

4.1 Natural Convection Correlations

The complexities of the fluid flow make it very difficult to obtain simple analytical relations for natural convection. Thus, most of the relationships in natural convection are based on experimental correlations. The Nusselt number in natural convection is in the following form:

$Nu=hL/K=CRa^n$ (1)

Where the constants C and n depend on the geometry of the surface and the flow

4.2 Forced Convection Heat Transfer

It is found that the Nusselt number can be expressed as:

$Nu=hL/K=CRe_L^m Pr^n$ (2)

Where C, m, and n are constants and L is the length of the flat plate.

The passive heat load is the heat loss due to convection & conduction of enclosed thermoelectric cabinet and calculated by using the following equation

$Q_{passive}=A\Delta T/(x/k+1/h)$ (3)

4.3 Coefficient of Performance

The Coefficient of performance (COP) of a thermoelectric module which is the thermal efficiency must be considered for a TE system. The selection of TEC will also be based on the COP factor. COP is the ratio of the thermal output power and the electrical input power of the TEC. COP can be calculated by dividing the amount of heat absorbed at the cold side of the input power.

$COP = Q_C / P$ (4)

$P = V.I$ (5)

5. RESULTS AND DISCUSSION

In this section the affecting parameter on the performance of thermoelectric devices are cooling, heating Sides and the air flow across the devices. The ranges of operating parameter are applied volt from 3 to 12 volts And Cooling air velocity from 0.0 to 12.5664 m/s.

5.1 Effect of applied of voltage on performance of Thermoelectric

5.1 For Hot Side

Fig. (4) shows the hot side temperature with time at different applied voltage. It is observed the hot side temperature increases with increasing time to 200 sec and then the rate of change is constant with increasing time. Also the temperature increases with increasing the applied voltage input of thermoelectric cooler.

Fig. (5) Shows the hot side temperature with time at different applied voltage .It is observed the hot side temperature increases with increasing time to 45 sec and then the stability of the temperature stability of both voltages applied variables in the thermoelectric reason is to increase the speed of the expulsion of heat from the hot side and reduce the load from the cold air to stop the speed inflicted it appears This in turn explains the decrease due to the thermal resistance.

Fig. (6) shows the hot side temperature with time at different applied voltage. It is observed, the hot side temperature increases with increasing time to 25 sec and then the stability of the temperature stability of both voltages applied variables in the thermoelectric reason is to increase the speed of the expulsion of heat from the hot side and increase the load of the running speed of the cold air meted it appears This in turn explains the decrease due to the thermal resistance and less time to stabilize.

Fig. (7) shows the hot temperature with time at different applied voltage. It is observed, The hot side temperature increases with time to 45 sec and then increases by a slight change to the source voltages applied to 3 volts and 5 volts is getting more and more in a 12-volt significantly, cause of this condition is a high load to close the air speed in the hot where convection resistance and of course at the same time increasing the applied voltage and the effect is clearly larger.

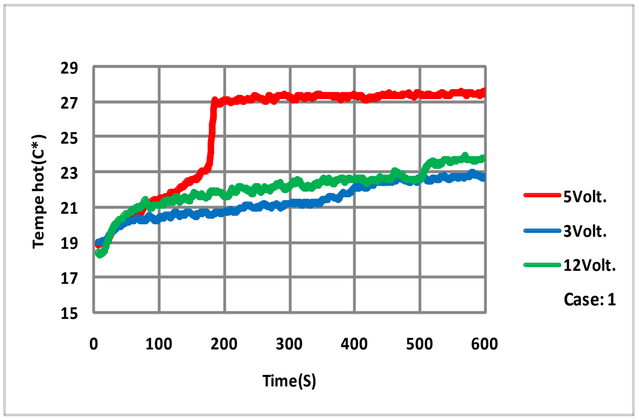

Fig. (4) hot side temperature with time at different applied voltage for case1

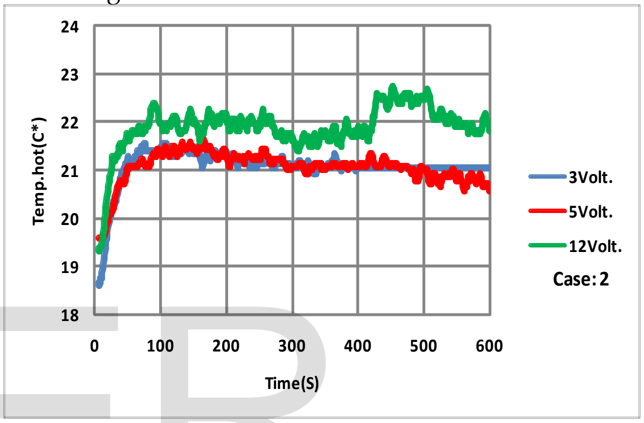

Fig. (5) hot side temperature with time at different applied voltage for case2

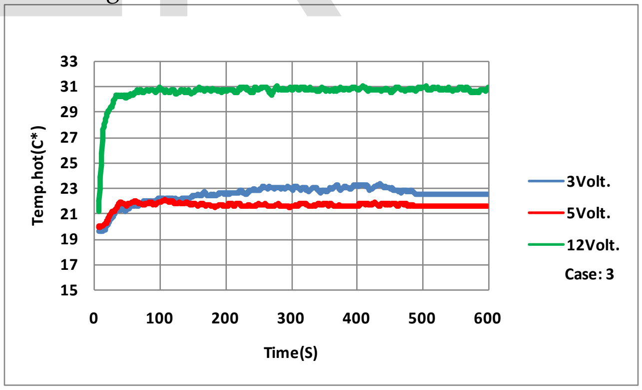

Fig. (6) hot side temperature with time at different applied voltage for case3

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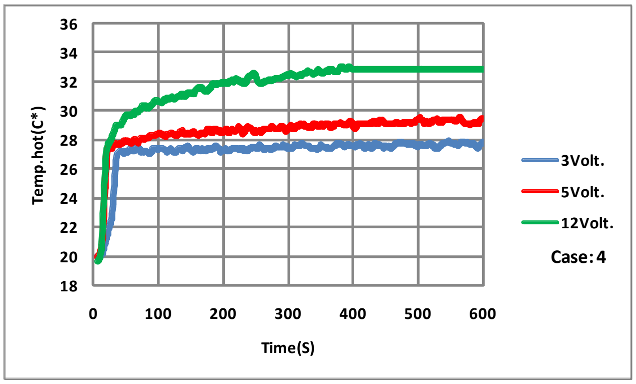


Fig. (7) hot side temperature with time at different applied voltage for case4

5.2 For Cold Side

Fig. (8) shows the cold side temperature with time at different applied voltage. It is observed, the temperature decrease in time to 25 sec after those temperatures to be Increase, when voltage read 3volt the temperature change is slow and stable, but when increase voltages, the temperature speed change

Fig. (9) shows the cold temperature with time at different applied voltage. It is observed, the temperature decrease at the voltages applied 3volt and 5volt but voltage 12volt, that be Increase at up time 300 sec, the voltage higher than the capacity of the fan on the side inflicted rejected heat means increased thermal resistance excessively

Fig. (10) shows the cold side temperature with time at different applied voltage. It is observed when up time 45 sec, voltages applied to 3 and 5 Volts the temperatures decrease but the applied 12Volt. Temperature increase, When meted increase the voltage higher than the capacity of the fan on the side inflicted rejected heat means increased thermal resistance excessively (behavior resembles that of the case of a fan running side hot and cold side closed).

Fig. (11) shows the cold side temperature with time at different applied voltage. It is observed, the temperature is decrease followed a significant rise in temperature with increasing voltages applied to the interpretation of the piece rate by increasing the voltage increase the thermal resistance and limits the expulsion of heat to stop the fans not enough to lower the temperature natural arranging

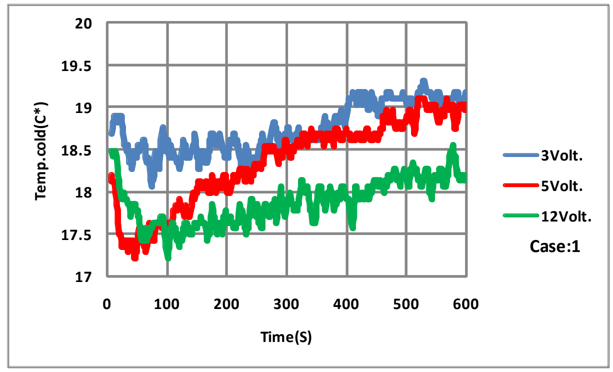


Fig. (8) cold side temperature with time at different applied voltage for case1

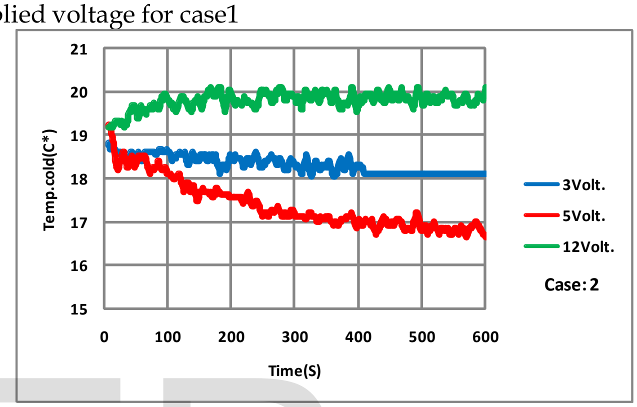


Fig. (9) cold side temperature with time at different applied voltage for case2

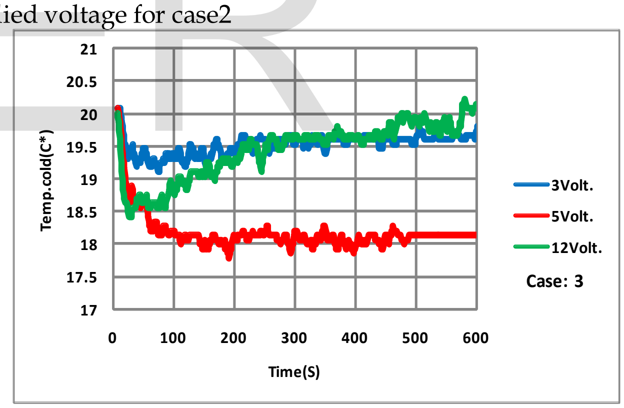


Fig. (10) cold side temperature with time at different applied voltage for case3

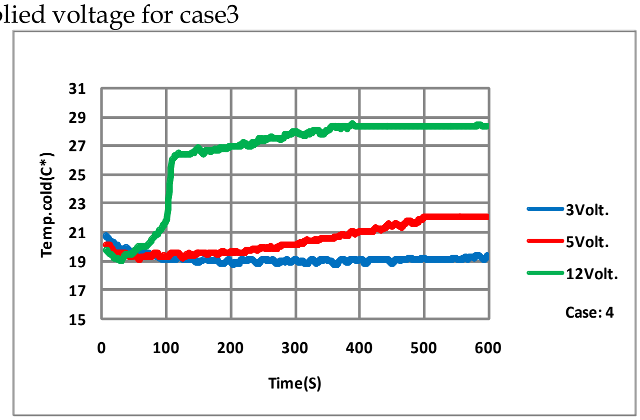


Fig. (11) cold side temperature with time at different applied voltage for case4

6. EFFECT OF FAN ON TEMPERATURE DISTRIBUTIONS

Fig. (12) shown the average hot temperatures with the power consumption for the three voltages and four cases processed and the status of operation of the fans It is observed the voltages applied 3volt and 5volt decrease hot temperatures for case 2

and case3 with low power when the temperatures increase at high power at voltages applied 12volt.

The voltages applied 3volt and 5volt increase hot temperatures for case 1 and case4 with low power when the temperatures increase at high power at voltages applied 12volt, that shows cas2 and case3 Semi state and case1 with case4 semi state

Fig. (13) shows the average cold side temperatures with the power consumption for the three voltages and

four cases processed and the status of operation of the fans It is observed the voltages applied 3volt and 5volt decrease hot temperatures for case1 and case2 and case3 but case4 the temperatures increase with low power when the temperatures increase in high power at voltages applied 12volt for all case, that case1, 2, 3 semi state.

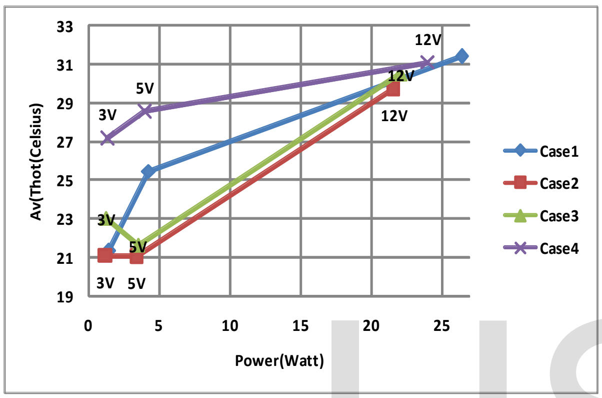


Fig. (12) The average hot temperatures with power consumption

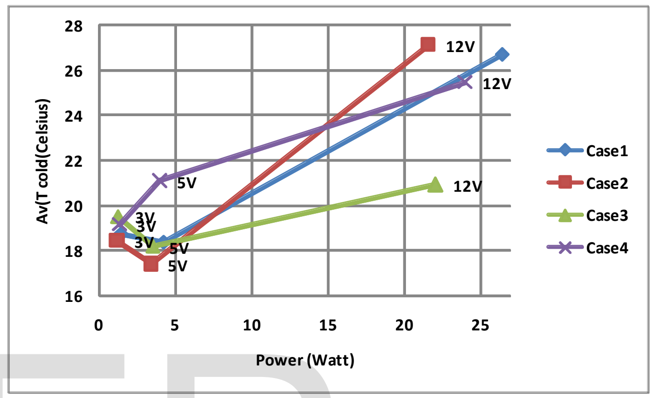
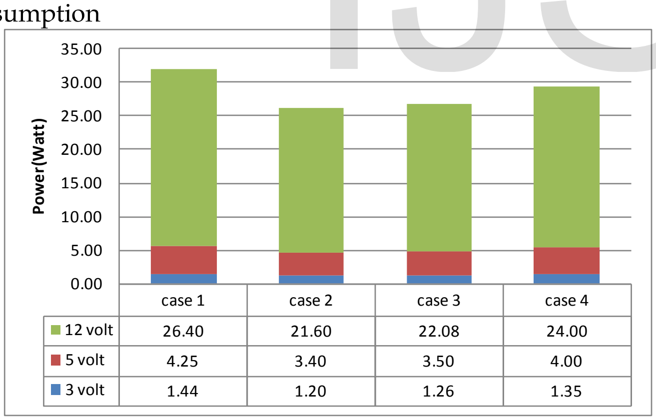
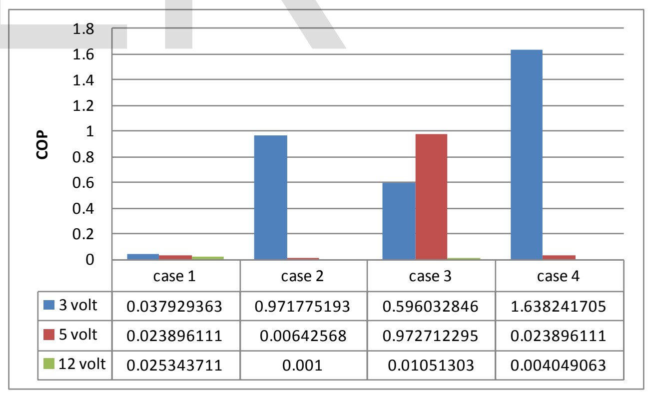


Fig. (13) The average Cold temperatures and the power consumption



	case 1	case 2	case 3	case 4
12 volt	26.40	21.60	22.08	24.00
5 volt	4.25	3.40	3.50	4.00
3 volt	1.44	1.20	1.26	1.35

Fig. (14) the fan case with the level of the power consumption at different applied voltage



	case 1	case 2	case 3	case 4
3 volt	0.037929363	0.971775193	0.596032846	1.638241705
5 volt	0.023896111	0.00642568	0.972712295	0.023896111
12 volt	0.025343711	0.001	0.01051303	0.004049063

Fig. (15) the fan case with the performance cooling COP at different applied voltage

From figs, 14, 15 it observed the minimum power consumption and maximum coefficient of performance occurs at lower values of the voltage applied.

7. CONCLUSION

A small scale of thermoelectric cooler is installed and tested on faculty engineering, Mansoura University. Performance of thermoelectric cooler is compared to the performance of the modified thermoelectric cooler. The modified system show an excellent power and energy consumption before our and a reduction on thermal resistor.

The hot side before increase with increasing applied Voltage, Thermal Resistance devises for increasing applied Voltage, Temperate difference creasing for creasing applied Voltage.

In the experiment that parameter voltages with 3 Volt read the lower readers Power and at same time COP increase, that reversed familiar when increase power and increase COP, back to that impact-resistant thermal and electrical resistance negative effect on the power.

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