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Design, Fabrication and Testing of Thermoelectric Cooling-Heating System

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ABSTRACT

Cooling may be defined as the process of achieving and maintaining a temperature below that of surrounding.The global increasing demand for refrigeration and air-cooling in field of food preservation, vaccine storages, medical services, and cooling of electronic devices, led to production of more electricity and consequently more release of CO_2 and CFCs all over the world and become a contributing factor of global warming on climate change. To overcome this problem, adopttion of thermoelectric energy is one of the best option. Thermoelectric refrigeration and air cooling is new alternative because it can convert electricity into useful cooling. It plays an important role in meeting today's energy challenges. Therefore,The use of thermoelectric cooing systems are greatly needed, particularly for developing countries where long life and low maintenance are needed. The objectives of this present study is to design, develop and test a working model of thermoelectric water cooling and air cooing system along with the drier system as a single unit which works on the Peltier effect principle. In this present study 5 sets of thermoelectric modules are used to cool the system. Hybrid insulation is provided to obtain a better perfomance. A pump is used to circulate the water which helps in improves the COP of the system.In this project, the ambient temperature of 34℃ is reduced to temperature of 18.6℃ for water cooling , 19.8℃ for aircooling and increased to 51℃ for drier with in 1hour. The refrigeration effect of the fabricated system at 120W power input is observed as 53.64W for water cooling, 76.99W for air cooling and 43.20W for drier system. The C.O.P at the same power as 0.894 for water cooling, 1.283 for air cooling and 0.720 for drier system.

Keywords *: Thermoelectric cooling, peltier module, air cooling ,water cooling.*

1. INTRODUCTION

Researches on energy-efficient green technologies and conversion of waste heat into useful work are being accelerated in order to reduce environmental issues such as global warming and pollution. Now a days , The conversion of energy is as important as its generation due to the energy demand increasing inevitably. One of attractive subjects on green conversion of energy is thermoelectric (TE) device that can be powered by renewable energy source such as PV cells. Despite commonly used in cooling applications, TE devices can also be used in heating applications. Furthermore, electricity power can be generated by maintaining a temperature difference between the surface of TE device using Seebeck effect. According to (1.Study on performance 2021) In this they noticed that conventional refrigeration system makes noise which gives negative impact .So They are trying to avoid this by coupling the thermoelectric modules with ionic wind fans .The new system will gives quite operation with optimum voltage consumption .The use of TE devices is principally preferred for its advantages of silent operation, long lifetime, being compact and environment-friendly, having no moving parts and no working fluid, requiring smaller spaces and no maintenance. On the other hand, their applications are limited due to the lower energy conversion efficiencies with respect to the other common systems

2.(Solar based Thermoelectric…2022) Refrigerator using the Peltier effect to maintain a specified temperature, perform temperature control in the range of 5C to 25C also authors explained how it will be ecofriendly.(3.Performance and …2020) A novel design of a portable solar thermoelectric refrigerator is proposed in this study. he cooling effect of the thermoelectric module is utilized to provide cooling to the refrigerator space from (4.CFD analysis for .. 2020) In this journal they work on Computational Fluid Dynamics (CFD) analysis was conducted considering three different turbulence models. The cooling time was observed 144min for getting cooling of around 10 degree Celsius. Simulation analysis of TEC modules is done in this paper. Seebeck (1826) discovered the TE effect which is the conversion of temperature difference between dissimilar metals to an electric current. Peltier (1834) proved the feasibility of Seebeck effect inversely such that the current applied is converted to a temperature gradient.

(5.Performance..2021) In this study, a novel building envelope integrated with thermoelectric cooler and radiative sky cooler (TEC-RSC) was proposed, not only for the elimination of heat gain through itself but also for space cooling. Through optimization design, the TEC-RSC can provide a cooling capacity of 25.49 W/m2 with a COP of 2.00 under the condition of global solar radiation.

In this study, the validation of TEC model and that of RSC model were conducted, respectively, to confirm the effectivity of the TEC-RSC model .(7.Design..2022) The objectives of this study is design and develop a working thermoelectric refrigerator interior cooling volume of 18L that utilizes the

Peltier effect to refrigerate and maintain a temperature from 33 °C to 22 °C. The design requirements are to cool this volume to temperature within a time period of 1hr and to obtain COP in the range of 0.2 to0.6.(9.Improvement..2017) The working parameters of thermoelectric refrigeration system are greatly affected by the operating voltage and the cooling efficiency. The designe used is increase of fin area and fan speed to improve its cooling capacity. The main problem over the use of TEC is the limited COP and its thermal performance. But these can be eliminated by use of multistage thermoelectric cooler.(10.Performance analysis..2018) This study experimentally investigates the performance of the single stage and multistage TEC air-cooling module. It is quite easy to achieve the significant temperature difference in the single stage TE module, but, the COP of the single stage module is very less for the domestic use.In the multistage TE module, It is possible to get the require COP as well as better thermal performance.(13.Experimental..2020) This paper reports the experimental analysis of a novel hybrid sorption-compression chiller for cooling and refrigeration purposes in cascade layout, which uses silica gel/water for the sorption cycle and a low Global Warming Potential (GWP) refrigerant, i.e. propylene for the compression cycle. (14. Performance..2020) A novel design of a portable solar thermoelectric refrigerator is proposed in this study. The cooling effect of the thermoelectric module is utilized to provide cooling to the refrigerator space.(15.Theoretical..2021) This paper aimed at obtaining the optimal cooling performance of the thermoelectric refrigeration box system. Three groups of experiments comprised of 17 working conditions were conducted, depending on the full scale experiments. (16.Design..2012) In this Journal they noticed that conventional refrigeration system makes noise which gives negative impact .So They are trying to avoid this by coupling the thermoelectric modules with ionic wind fans. (17.Performance..2013) In this Journal they noticed that TEC is a versatile component that is very compact in size as compared to a compressor-based system that works on the Peltier principle.(18.Performance..2020) A novel design of a portable solar thermoelectric refrigerator is proposed in this study. The cooling effect of the thermoelectric module is utilized to provide cooling to the refrigerator space .(19.Theoretical..2017) In this journal they work on Computational Fluid Dynamics(CFD) analysis was conducted considering three different turbulence models.(20.Experimental..2017) In this study, a novel building envelope integrated with thermoelectric cooler and radiative sky cooler (TEC-RSC) was proposed, not only for the elimination of heat gain through itself but also for space cooling.(21.Experimental..2020) In this article, an aggregation strategy is proposed to fulfil system operator requests on power deviations with limited information exchange between the aggregator and each refrigerator.(22.Numerical..(2019) In this article, three dimensional numerical simulations have been performed for the optimization design of a compact TEC .(23.Solution..2017) This paper focuses on the potential of exploiting thermoelectric cooling as an interesting option to be applied in a refrigeration.(24.Theoretical..2017) This paper aimed at obtaining the optimal cooling performance of the thermoelectric refrigeration box system.

Table 1

Summary of results obtained in recent studies on TECs.

Reference	TEC technology/model	Hot side/Cold side heat sink	COP
(Manikandan et al., 2017)	Modified pulse operation of 24 TECs in series	Natural convection/ Natural convection	1.01
(Gokcek&Sahin , 2017)	Single TEC/TEC1-12709	Minichannel, forced water/Forced air	0.18
(Astrain et al., 2016)	96 TECs in parallel/Marlow DT12-8L	Forced water/Air; Heat Pipe/Air; Air/Air	0.42-0.77
(Qian and Ren, 2016)	Transverse TEC	-/-	0.59-1.50
(Martinez et al., 2016)	Two TECs in series/Marlow RC12-6L	Forced air/Natural convection	0.09-0.33
(Hu et al., 2016)	Single TEC/TEC1- 26315	Forced water/CPU (electric heater simulated)	0.5-1.4
(Wang et al., 2015)	Two-stage TEC in series	-/-	0.33
(Ohara et al., 2015)	Single TEC/Laird PT 40	Forced air/Planar heat pipe	0.3
(Jeong, 2014)	Single TEC	-/-	1.1

Optimization studies on the subject are generally based on theoretical or numerical models although they include investigations on both operational and design (or geometric) parameters. There is a lack of optimization study performed using experimental methods. On the other hand, there is a limited number of researches on thermal performance of TE refrigerator at varying fan powers at both sides of TE material although some similar studies on the effects of varying TE currents exist in the literature. Additionally, there is no document regarding the effect of ambient temperature as an operational parameter. In this study, a TE refrigerator that works based on Peltier effect is designed and constructed. The TE refrigerator is tested for different rotational speeds of fans and different working powers of the Peltier device as well as different ambient temperatures. They are all the operating conditions that influence the performance of the system. Using the results of the experiments, an optimization for the operational conditions that maximize the COP of the system is performed. The investigation of the COP variation of the TE refrigerator with different fan speeds (or powers) and optimization of a TE refrigerator are the originality and novelty of this study.

2. MATERIAL AND METHODLOGY

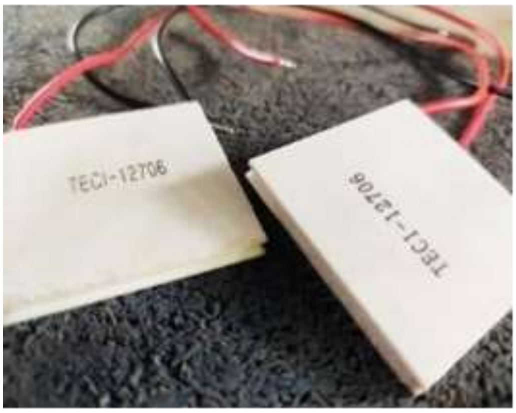

Figure 2.2 Aluminium heat sink

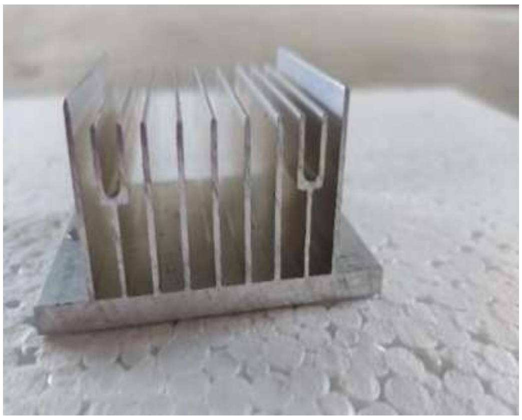

Figure 2.1 Silicon- germanium TEC module

2.1 Working principle of Peltier element

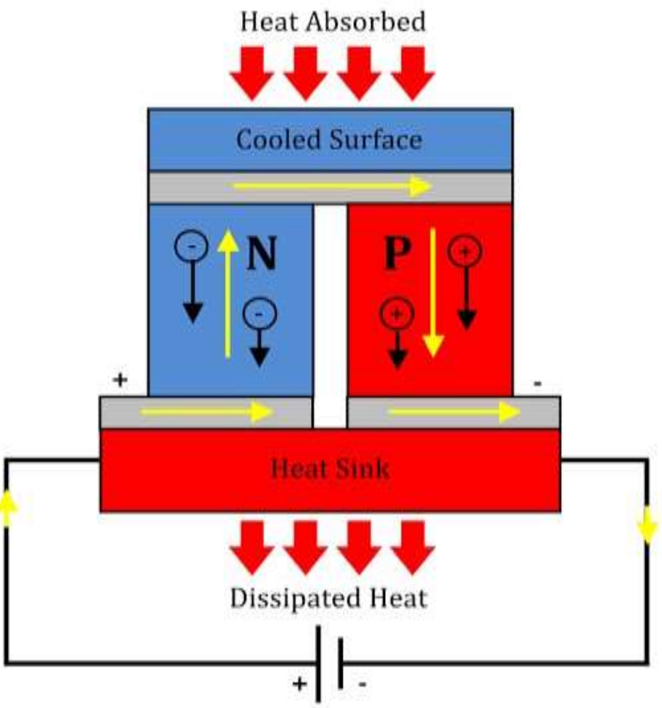

Fig. 2.3 Principle of peltier effect

A Peltier element can be used for heating and cooling or generating electricity. Two different semiconductors called N- and P-type semiconductors are welded to a conductor, usually copper, on both sides. The semiconductors are sandwiched between the copper plates coated by ceramic layers for electrical insulation. Electrons can travel freely in the copper conductors but not so freely in the semiconductors. As the electrons leave the copper conductor and enter the hot side of the P-type, the electrons fill a hole in order to move through the P-type and they drop down to a lower energy level and therefore release heat to the hot side. As the electrons move from the P-type into the conductor on the cold side, they are bumped back to a higher energy level and absorb heat from the cold side . Same process occurs for the N-type semiconductor. Thus, a temperature difference is occurred by circulating an electric current through the junction of two different semiconductors. The degree of heating or cooling is predominantly determined by the type of semiconductor metal (generally bismuth telluride) used in the production of Peltier element.

2.2 Experimental Setup

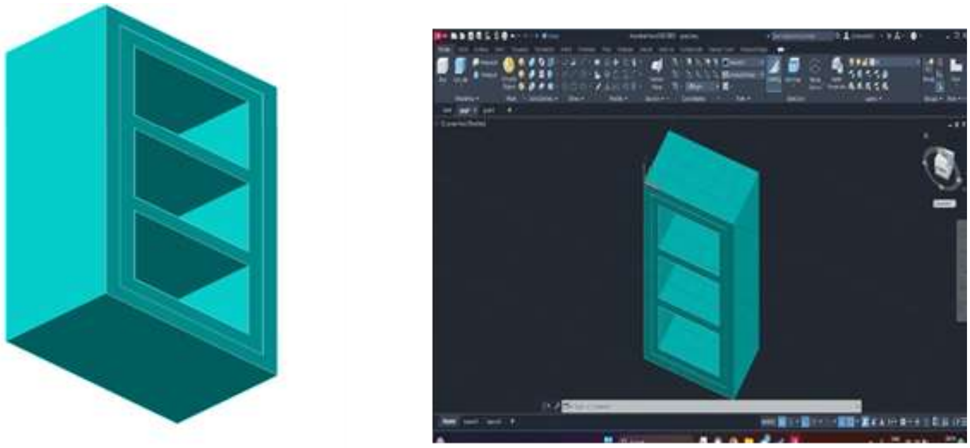

Fig.2.4 Autocad 3D modeling of prototype

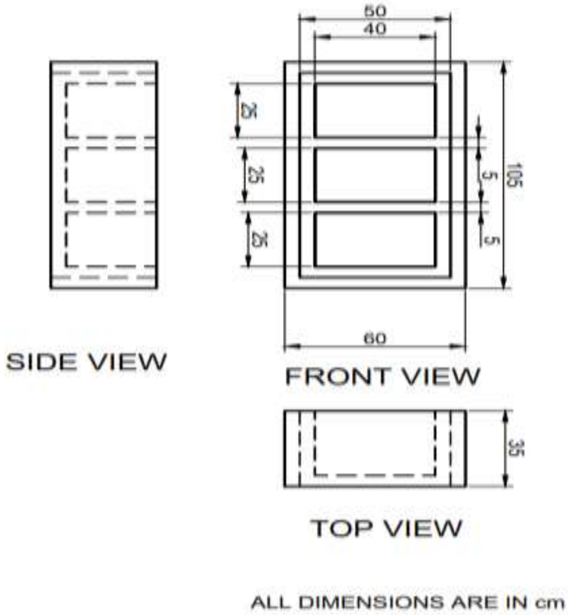

Fig 2.5 Interior body of Thermoelectric refrigeration system

Table no 2.1: Outer dimensions of TEC set up

s.no	Dimesion	Value in cm
1	Length	105
2	Breadth	60
3	Width	35

Inner dimensions of the each cabin

Table no 2.2: Dimensions of water cooling cabin

S.no	Dimesions	Value in cm
1	Height	30
2	Length	60
3	Width	35

Table no 2.3: Dimensions of air cooling cabin

S.no	Dimesions	Value in cm
1	Height	30
2	Length	60
3	Width	35

Table no 2.4: Dimensions of drier cabin

S.no	Dimesions	Value in cm
1	Height	30
2	Length	60
3	Width	35

3. FABRICATION

The TE refrigeration system consist of a Peltier device, Insulated box with dimensions 105x60x30 cm (0.189 m^3 volume), plate-fins (heat sinks), Submergible Pump , Transparent tray (40x19x22 cm), axial fans. The plate-fins and axial fans are mounted on both sides of the TE device to dissipate heat easily. The hot side of TE device must be cooled well in order to obtain low temperatures on the cold side. Because of this, a fan is usually used on the hot side of TE devices. On the other hand, a fan on the cold side is optional and used to blow the cold air into the box and obtain a uniform temperature inside the box. The current installation direction of the fans is chosen due to the better heat transfer performance with respect to the inverse installation direction according to initial test results. Both fans have 12 V input voltage, but the outer fan (i.e., the fan on the hot side of the Peltier element) is more powerful and has higher amperes than the inner fan (i.e., the fan on the cold side of the Peltier element). The fins (heat sinks) are made of aluminum.

3.1 Materials and Measurement devices used

A digital Multimeter used to measure the working voltage and current of fans. Digital temperature sensors are used to measure the temperatures at four points inside the refrigerator box. Four temperature sensors measures cooling water temperature inside the water tray while the other thermocouple measures the air temperature in the hot cabin , one more is used to measures the temperature air cooling chamber

Table 2.5 Components used for fabrication

Sl.NO	Component	Specifications	Quantity
1.	 TEC1-12706	• Current=6A • 127 Couples • Voltage – 12V • Semiconductor	5 Nos.

2.	 Heat Sink	• Aluminium • Protrusion design	5 Nos.
3.	 Cooling Fan	• Voltage 12v • Current 5A • BLDC	5Nos.
4.	 Rectifier	• AC to DC • Voltage -12V • Current -5A	2Nos.
5.	 Thermopaste	• 5gm	2Nos.

6.	 Submergible Pump	• Current=6A • Voltage – 12V • Discharge : 10L/min	1No.

7.	 Digital Temp. Sensor	• +150 degree to -10 degrees	4Nos.
8.	 Aluminum Sheet	• 150cm X 120cm	1No.
9.	 Rectangular bar	• AC to DC • Voltage -12V • Current -5A	1No.
10.	 Transperant water tray	• 40cm x 22cm x 19cm	1No.
11.	 Electric wire	• 3m wire	1No.

3.2 Experimental Procedure

Before starting an experiment, the voltages of the fans and Peltier element are adjusted and recorded. The experiment is started when all the temperatures measured are in equilibrium with the ambient temperature. Temperature measurements are recorded at 3-minute intervals. The period for an experiment is 60 minutes. This period is selected due to that steady state conditions are observed after about 60 minutes. The temperature of the air inside the TE refrigerator is taken as the average of the four temperature measurements.

Fig.3.12 Final Working model of Thermoelectric system

4. RESULTS AND DISCUSSIONS

Table 4.1 Experimental Results of air cooling

S. No	Time (Min)	Temperature (°C)
1	0	34.00
2	10	27.20
3	20	25.60
4	30	23.40
5	40	21.90
6	50	20.40
7	60	19.80

Table 4.2 Experimental COP Results of Air cooling

S. No	Time (Min)	Temperature (°C)	Refrigeration effect(W)	C.O.P
1	10	27.20	221.22	3.687
2	20	25.60	136.64	2.277
3	30	23.40	114.95	1.915
4	40	21.90	98.41	1.640
5	50	20.40	88.49	1.474
6	60	19.80	76.99	1.283

After doing the experiments based on the results we are plotting the below graphs

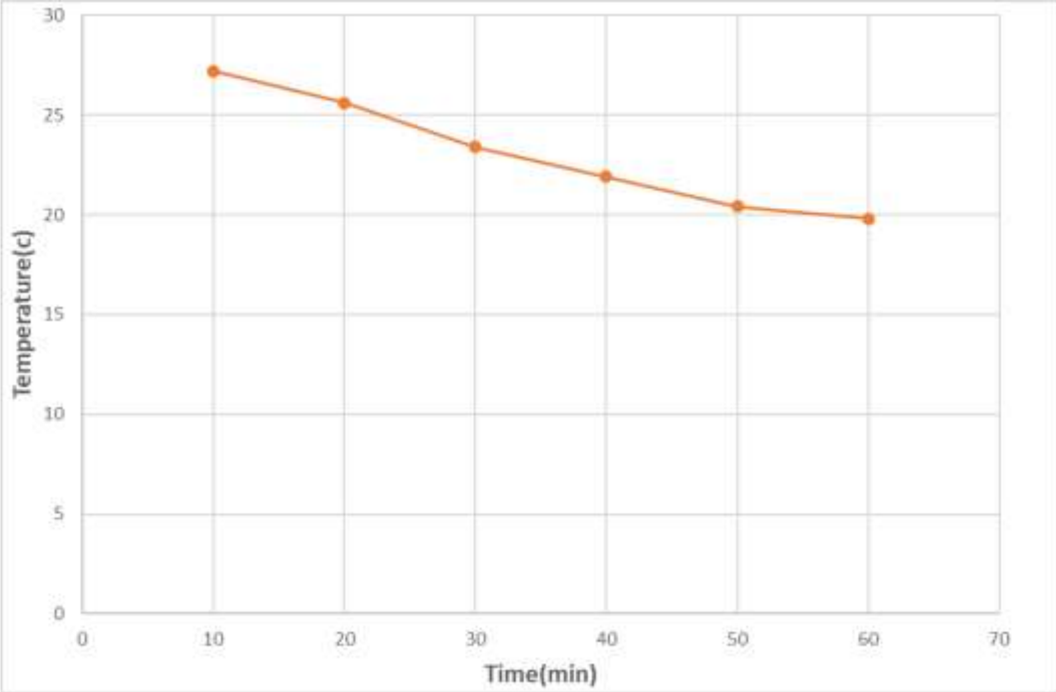

Fig 4.1 Time Vs Temperature

Based on the above behavior of the graph we can easily said that by the gradual increasing of the time the temperature of the system will be decreasing. In the span of 60 min it will decrease maximum upto 19.8 degrees.

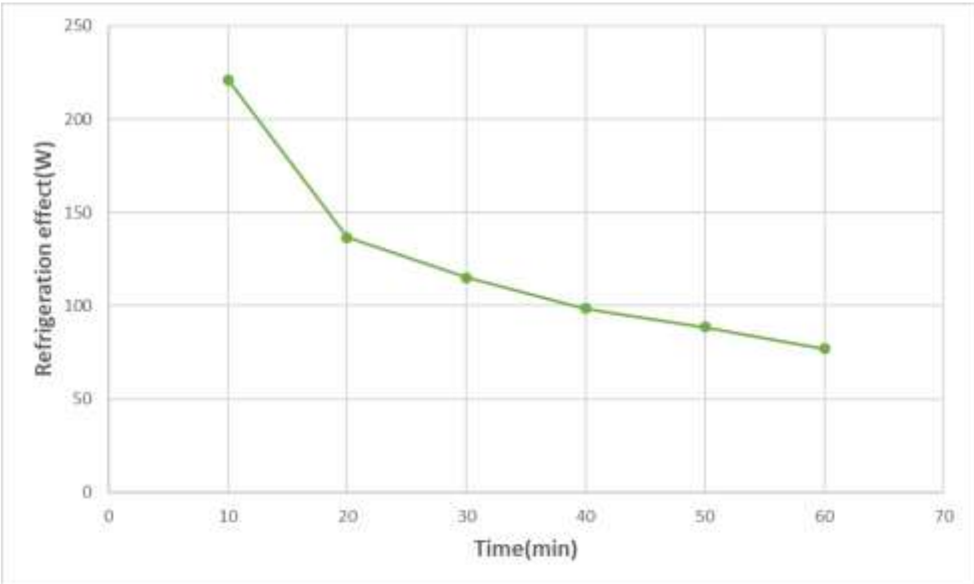

Figure 4.2: Time Vs Refrigeration effect

Based on the above behavior of the graph we can easily said that by the gradual increasing of the time the Refrigeration effect of the system will be decreasing . In the span of 60 min it will decrease maximum upto 76.00` KW.

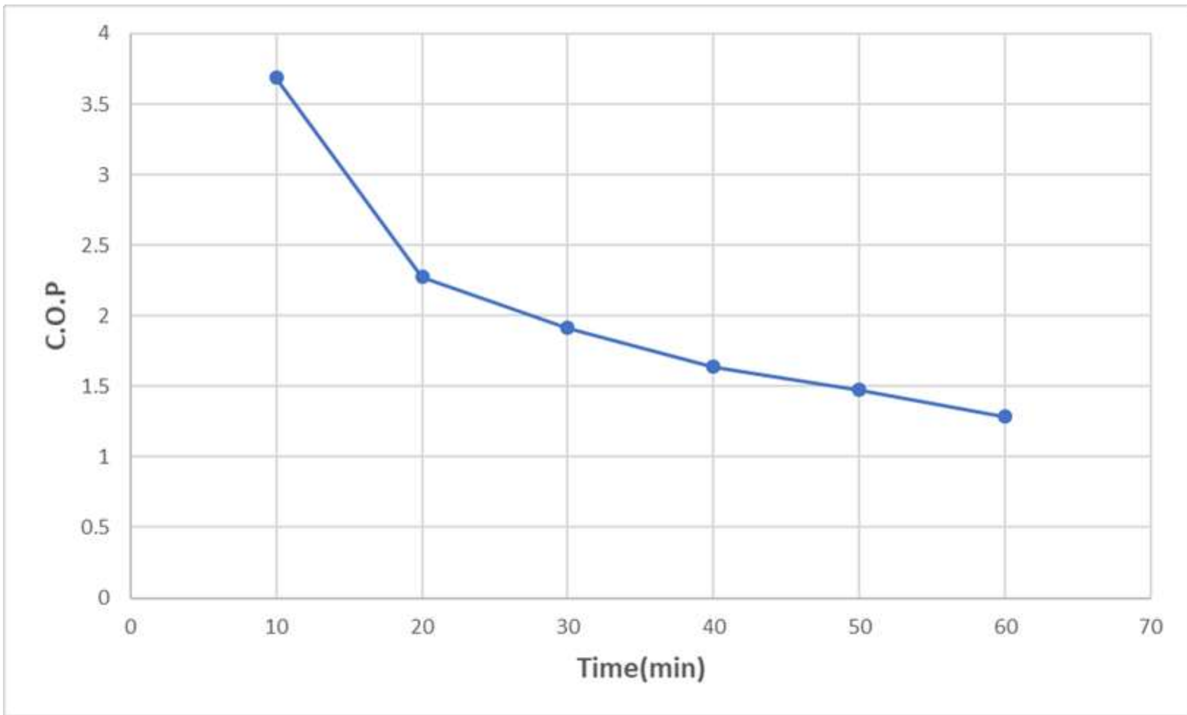

Figure 4.3: Time Vs C.O.P

By this we can conclude that by the gradual increasing of time the COP of the system will be decreasing slightly initially it will be higher the it is decreasing because of the over increasing the time the power consumption will be increased so that the cop will be degreased from 3.687 to 1.283.

5. CONCLUSION

In this present study a thermoelectric air cooling system have been successfully fabricated and tested and it fulfills the proposed goals. In the present project, the ambient temperature of 34℃ is reduced to 19.8℃ for air cooling system with in 1hour. The refrigeration effect of the fabricated system at 120W power input is observed as 76.99W for air cooling 1.283 for air cooling. We can deduct from the given facts that thermoelectric cooling systems add a new dimension to cooling and heating. The prototype fabricated in this work is espically useful for domestic applications to store the food products like milk, oil, chips, salt, sugar, cheese,butter. Other beverages can also be chilled. It has a significant impact on the conventional system. Thermoelectric cooling systems are small in size, have no frictional parts, require no coolant, and are light in weight. Before it can be issued for effective field use, it must undergo extensive adjustments.

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