DESIGN AND FABRICATION OF THERMOELECTRIC SOLID-STATE AIR CONDITIONER

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Abstract

In this study, we designed and fabricated of thermoelectric solid-state air conditioner (TESSAC) within 400 BTU/hour by using a thermoelectric cooling (TEC) module (model: TEC1-12710) for 3 modules. Thermal management was carried out with the aluminum water-to-radiator system through the liquid moly coolant for controlling the temperature on the hot side of the TEC module. The cooling performance and electrical power were measured during the operating system as performed in one cubic meter for 3 h. According to the experimental results, the TEC1-12710 of one module could be generated cooling by decreasing the temperature to -8.5°C. After useful TEC of 3 modules as useful TESSAC fabrication, TESSAC could be cooled at the cold side around 9.3°C, then the temperature at the center simulation room is around 27.5°C within the ambient temperature of 33.5°C. The coefficient of performance (COP) of TESSAC was calculated to be obtained around 5.5 with the AC power used of 202.31 W.

Keywords: Thermoelectric solid-state air conditioner, thermoelectric cooling, liquid moly coolant

Introduction

Air conditioners were first made in the 1900s by using the process of dehumidification, which involves condensing the water vapor in the air to form water droplets, then sending cold air with low humidity instead. The air conditioners available on the market today use refrigerant, which has been continuously developed (Saini *et al*., 2011). These results are increased energy consumption, emissions of greenhouse gases, and noise from the operation of the system. For example, in the United States,

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electricity accounted for more than 76% of total consumption, more than 40% of all types of energy consumption and related greenhouse gas emissions occur in the building sector. Heating, ventilation, and heat pump air conditioning are account for 35% of both residential and commercial energy use which energy consumption is increased. The share of annual electricity consumption is rose from 25% in the 1950s to 40% in the early 1970s and to 76% in 2012 (Gao *et al*., 2021).

Unlike solid-state refrigeration systems, current compression cooling technology does not use refrigerants or compressors. It has significant advantages in terms of zero emissions and noise (Ma *et al*., 2017; He *et al*., 2021). The thermoelectric also has a service life of more than 100,000 h (Charilaou *et al*., 2021). It is a solid-state cooling system that uses the Peltier effect to obtain cooling from a thermoelectric source. Thermoelectric cooling technology is one of the most promising. It is an alternative technology of the 21st century (Zuazua-Ros *et al*., 2019). The thermoelectric refrigeration systems were devel oped and applied in the air conditioning field Ventilation and heating are two of the major trends for the future.

Adeyanju and Manohar (2020). reported prototype thermoelectric air conditioner with a cooling capacity of 286 W using three Peltier TEC1-12730 modules with an installation of the heatsink on the cold side of the thermoelectric. The experiment was conducted in a foam box, measuring 1.6414 m^2. It was found that it took a thermoelectric air conditioner 4 min to reach the desired temperature of 22°C, while a standard air conditioner system (the refrigeration cycle) took 20 min to cool down to room temperature. The experiment was determined the cooling efficiency using a thermoelectric (TEC1-12708, China) and performed by installing the heatsink to cool both the cold, hot sides by using the hot side cooling fan, spreading the coolness on the cold side and optimum current of 1 A. The cooling capacity is 29 W with a COP of 0.34, a cold air temperature of 28°C, and an air velocity of 0.9 m/s (Maneewan *et al*., 2010). Thermoelectric analysis method based on thermoelectric mathematical modeling to study the effect of the thermoelectric properties of materials on power based on four thermoelectric air-cooling systems: 1) Scenario 1: α, σ, and κ changing in equal proportions 2) Scenario 2: α, σ, and κ changing for equal zT values 3) Scenario 3: α, σ, and κ changing for maximum of COP 4) Scenario 4: Relationship of the maximum COP with the zT value and a constant voltage of 4 volts. During the experiment, water circulated from the water tank that was equipped with a fixed frequency pump measured by two high-precision power meters and a T-type thermocouple sensor. The temperature of the TEM critical points was measured using this device and four sensors were evenly placed on the surface of the heat pipe. The study also measured the temperature of the sensor facing the center of the module for thermoelectric material applications. The cooling efficiency of the thermoelectric air-cooled system has been significantly increased when the temperature difference between hot and cold is reduced for applications with small temperature differences. Modules with higher α values were offered better performance with thermoelectric materials of the same virtue. According to the experimental results, the thermoelectric performance is sensitive to the α and the optimum value is the increasing zT (Duan *et al*., 2021).

In research work, we have designed and fabricated of thermoelectric solid-state air conditioner (TESSAC) within 400 BTU/h. The experimental to find the suitability of the construction, cooling performance, and electrical power useful of TESSAC were investigated and reported.

Nomenclature

TEC	Thermoelectric cooling
zT	Dimensionless Figure of merit
COP	Coefficient of performance
Q_h	Heat energy produced on the hot side
Q_c	Cooling energy produced on the cold side
Q_E	Electrical energy input
T_c	Cold side temperature of TEM
T_h	Hot side temperature of TEM
TESSAC	Thermoelectric solid-state air conditioner

Greek Symbols

α	Seebeck coefficient value of TE material
σ	Electric conductivity value of TE material
κ	Thermal conductivity value of TE material

Materials and Methods

The fabrication of TESSAC was used the TEC module with the TEC-12710 model as shown in Figure 1, conclude the performance Table 1. The dimension of TEC module is 40×40×3.2 mm^3 and then specific data showed V_{max} = 15.2 V, I_{max} = 10.5 A and Q_{max} 85 W.

Figure 2 shows the experiment as produced with the current of 5.90 A apply to TEC for investigating on the cooling efficiency of the cold side in the experiment for 3 h (10,800 s).

Table 1. Specific data of TEC module

Hot side temperature (°C)	25°C	50°C
Qmax (Watts)	85	96
Delta Tmax (°C)	66	75
Imax (Amps)	10.5	10.5
Vmax (Volts)	15.2	17.4
Module Resistance (Ohms)	1.08	1.24

Figure 1. (a) Specific data of TEC module and (b) TEC module of TEC-12710 model

The temperature at cold side of TEC was suddenly decreased from 26.8°C to 11.1°C in during time 60 s and then slightly decreased and tended constant at -7.85°C after 3,600 s. While the hot side temperature is increased with exponential curve from 26.8°C to 31.9°C and then tended constant at 31.9°C after 1,800 s.

The thermal management was play an important role because, when electricity is supplied to the thermoelectric, it causes cooling on the cold side and heating up on the hot side. Therefore, an optimal cooling method is discovered. The second law of thermodynamics was calculated the heating and cooling that take place when an electric current is applied as shown in the equation below (Ma *et al*., 2019):

$$Q_h = Q_c + Q_E \quad (1)$$

The TESSAC was designed conditioning relies system of 400 BTU/h by using TEC principle and cooling temperature on the thermoelectric hot side as shown in Figure 3. This process was performed by providing a water cooling system to make the air conditioning system work and used the fan control circuit to send cool vapor out of the front of the machine to distribute the cold.

From Figure 3, Figure 3(a) showed TESSAC sectional compose of 1) cooling generation position or TEC modules compact with water-cooled aluminium mounting plate as enlarged in Figure 3(c), 2) DC power supply for TEC, 3) cooling radiator, 4) water pump 12 V (water flow rate 300 L/h), 5) fan air flow, 6) air flow grille and 7) air

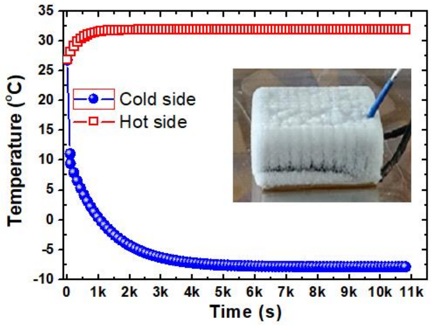
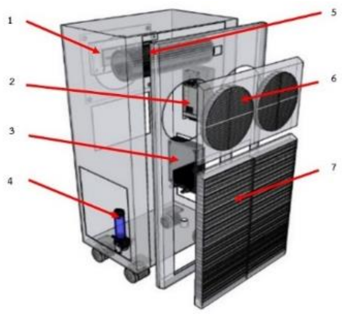
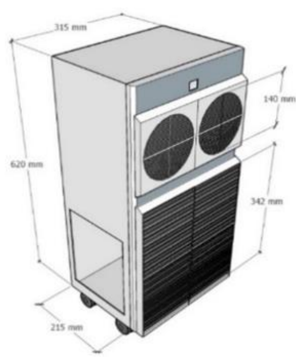


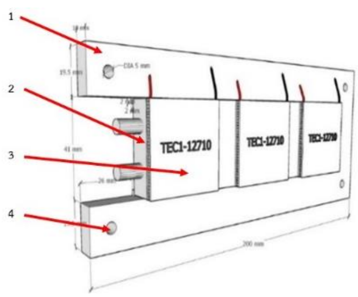
Figure 2. Cold side and hot side temperature of TEC module as produced with the current of 5.90 A for 10,800 s



(a)



(b)



(c)

Figure 3. (a) TESSAC sectional image, (b) overall view and dimensions and (c) TEC modules compact with water-cooled aluminium mounting plate

vents to ventilate air and filter dust into the machine. The dimensional of TESSAC are displayed in Figure 3(b) as obtained 315 mm of width, 215 mm of length and 620 mm of height. Figure 3(c) is enlarged cooling generation position or TEC modules compact with water-cooled aluminium mounting plate consist of 1) aluminium plate supporting TEC modules, 2) water-cooled aluminium mounting plate, 3) TEC modules and 4) screw hole to hold tight. The TESSAC was created and activated in a simulated room of 1 cubic meter for 3 h, the results as following by Figure 4. The cooling efficiency of TESSAC was determined in terms of cooling ability, temperature difference of thermoelectric. The difference temperature indicated the efficiency of cooling as shown in the Equation (2) (Sulaiman *et al.*, 2018; Ma *et al.*, 2019).

$$COP = \frac{1}{(T_h - T_C)} = \frac{T_C}{(T_h - T_C)} \tag{2}$$

Results and Discussion

The performance of TESSAC as used TEC for 3 modules was illustrated in Figure 5 as performed by the temperature measurement for cold side (T_c), hot side (T_h), center of simulation room (T_{cr}) and ambient (T_a) to be determined the coefficient of performance (COP) values as following the Equation (2). Also, the AC electric power to support TESSAC was measured and reported in Figure 5(d).

The temperature of hot and cold side thermoelectric is shows in Figure 5(a), which test of turning for 3 h. It was found that the temperature of cold side is decreased from 30.5ºC to 5.1ºC within 30 s and then increasing to 15.5ºC within 570 s. Hence, the cold side is average temperature of 9.3°C and the hot side average temperature of 40.12°C to be generated the temperature difference of 30.82°C. The temperature of TESSAC matter of simulation room was showed in Figure 5(b) to be compared with the cold side and ambient temperatures. The thermoelectric air conditioner was simulated room built with a size of 1.0×1.0×1.0 m^3 for 3 h. It was found that the average temperature at center room of around 28°C, and the ambient temperature of 33.16°C. Therefore, an average temperature difference between the room and the ambient temperature is 5.16°C. Figure 5(c), the evaluate of COP of TESSAC after operating 60 s is around 12.5, then decreased with steps to 10.7 at 600 s and 9.3 at 2,300 s to be tended to constant. Finally, AC electrical power applied to TESSAC was shown in Figure 5(d). The TESSAC was consummated

Figure 4. Instrumentation, air conditioning experiments

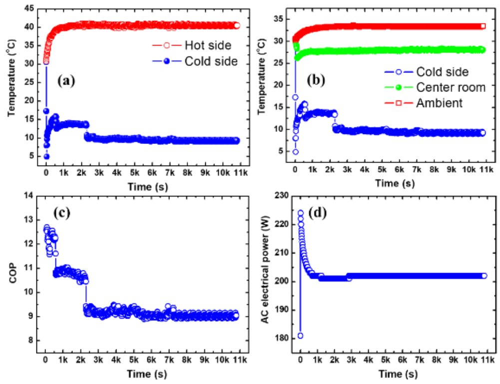


Figure 5. (a) The temperature of the hot side and cold side at cooling generation position, (b) The temperature of cold side, center of simulation room and ambient, (c) COP calculation values and (d) the electric power (AC) as supported TESSAC operating

electrical an average voltage of 223.04 Vac, an average cur rent of 0.907 Aac, and the average power of 202.3 W, which switching to DC current as supplied for TEC1-12710.

Conclusions

We achieved to designing and fabrication on TESSAC within 400 BTU/h by using TEC model: TEC1-12710 for 3 modules. The experimental result of TEC one module could be generated the maximum cooling as performed with temperature decrease to -7.85°C within DC current applied of 5.90 A for 3,600 s. For TESSAC fabrication, the results showed that the temperature of hot and cold side were 40.12°C and 9.3°C, respectively, to be obtained the temperature difference of 30.82°C and evaluated of COP value of around 9.3. The average temperature at center of simulation room is around 28°C within the ambient temperature of 33.16°C. The average AC power of 202.3 W was used to switching DC current for supplying the TEC1-12710.

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