THE EFFECT OF HEAT SINK VARIATION ON AIRFLOW PROPERTIES ON THE THERMOELECTRIC COOLING BOX: AN EXPERIMENTAL STUDY

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ABSTRACT

The further development of electronic technology, the higher the competition for developing electronic components. One solution is to use heat sink components to help release heat from electronic components into the environment. Variation in the shape of the heat sink to increase the heat transfer of performance, research was carried out on thermoelectric cooler box with different heat sink profiles to determine the best heat sink selection by analyzing the heat flow rate of the thermoelectric cooler. The experimental research was carried out on a plastic cooler with 150 mm x 150 mm x 210 mm, which serves as an insulator on the inner side of 15 mm thickness. The thermoelectric module used is the TEC-12706 with a DC power source using a 12V, 20 A power supply. Varied aluminum heat sinks are 200mm x 120 mm x 35mm with a straight profile (heat sink 1) and a heat sink measuring diameter 90 mm x 30 mm with a circular profile (heat sink 2). Based on the results of testing and analysis, it can show that the best performance on the thermoelectric cooler is the use of a heat sink with a straight profile measuring 200mm x 120 mm x 35mm. The use of electric power for the thermoelectric 19.5 W, the heat absorbed on the cold side (q_c) 17.5 W, heat which is released on the hot side (q_h) 37 W, heat absorbed from the cooling room air (q_a) 0.018 W, heat absorbed from the cooling room wall (q_w) 17.4 W, COP_C is 8.4 and $COP_{eksp.}$ is 0.8.

***Key words**: heat sink, cooler box, thermoelectric, COP*

1. INTRODUCTION

The agile development of electronic technology triggers higher competition for the development of electronic components. Utilizing a thermoelectric as one of a cooling engine's electronic components requires good thermal management to obtain a lower cooling room temperature [1]. One solution is to use a heat sink component to release heat from electronic components into the environment [2].

The heat sink performance derives from forced convection, natural convection, or liquid cooling. Typically, electronic assemblies are made of right thermal conduction materials such as aluminum or copper. Heat transfer on the heat sink fins, apart from being able to occur by convection, also occurs by radiation [3]. There are several heat sink profiles available, and they are tailored to suit each specific need. However, the most common heat sink profiles are parallel fins [4] [5].

Variation in the heat sink shape aims to increase the heat transfer of a performance [6][7]. Installing the heat sink for best performance is placed on the wall of the cooler [8]. Based on some of the descriptions above, research was carried out on thermoelectric cooler boxes with different heat sink profiles to determine the best heat sink selection by analyzing the heat flow rate in the thermoelectric cooler box.

Heat absorbed on the cold side of the thermoelectric module

$$\dot{q}_c = 2N\left[\alpha_m \,.\, I \,.\, T_c - K_m \,.\, \Delta T \,.\, G - \left(\frac{I^2\rho}{2G}\right)\right] \quad (1)$$

N is the number of connection elements in the TEC1-12706, α_m is the Seebeck coefficient of element [V/K], I is the electric current in the thermoelectric [A], T_c is the cold side temperature of the thermoelectric [K], K_m is the thermal conductivity of the element [W/cmK], ΔT is the temperature difference between the hot and cold sides of the thermoelectric [K], G= 0.121 cm; element geometry facto (AZTEC software) [9], ρ is the electrical resistance of the element [Ωcm].

Heat absorbed from the air in the cold room

$$\dot{q}_a = \frac{m \cdot C_p \cdot \Delta T_{air}}{\Delta t} \quad (2)$$

$\dot{q}_a$ is the heat absorbed from the air in the cooling chamber [W]; m is the mass of air in the cooling chamber [kg]; Cp is the specific heat of air [J/kgK]; ΔT_{air} is the difference between air temperature [K]; Δt is the time difference [s].

The electric power used is thermoelectric

$$P_{in} = I^2R + \alpha_m(T_h - T_c)I \quad (3)$$

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P_{in} is the electric power used by the thermoelectric [W], R is the electrical resistance [Ω], T_h is the temperature of the thermoelectric hot side [K].

Energy Balance

The energy balance equation can be determined that the heat released on the hot side of the thermoelectric module (q_h) and the heat from the wall of the cooling room (q_w) can be determined.

$$\dot{q}_h = \dot{q}_c + P_{in} \quad (4)$$

$$\dot{q}_w = \dot{q}_c - \dot{q}_a \quad (5)$$

COPc is a COP Carnot that can be determined from equation (6).

$$COPc = \frac{T_c}{T_h - T_c} \quad (6)$$

Empirically, COP can be determined in equation (7) by determining the heat value ratio absorbed on the thermoelectric's cold side to the amount of electric power used in the thermoelectric. Furthermore, COP_{eksp} value on thermoelectric chillers is smaller than COP's steam compression refrigeration engines [6].

$$COP_{eksp.} = \frac{\dot{q}_c}{Pin} \quad (7)$$

2. EXPERIMANTAL METHODE

Experimental research was carried out in a plastic cooler with a 150 mm x 150 mm x 210 mm size, which was coated with a styrofoam insulator on the inside of 15 mm thickness. The thermoelectric module used is the TEC-12706 with a DC power source using a 12V, 20 A power supply. Varied aluminum heat sinks are 200mm x 120 mm x 35mm with a straight profile (heat sink 1) and a heat sink measuring 90 mm x 30 mm with a circular profile (heat sink 2). The heat sink is attached to the side of the cooler [4]. Data were collected at four points: cold side temperature, hot side temperature, cold room temperature, and ambient temperature for 1800 seconds, as shown in Figure 1.

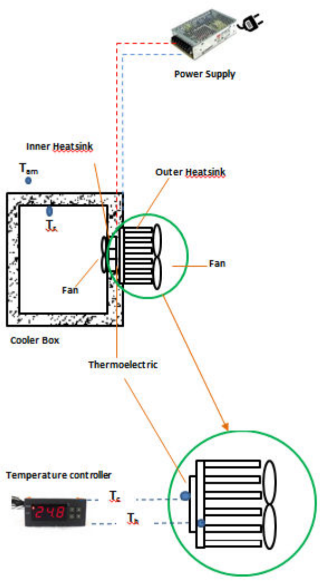

Figure 1. Schematic of Experimental Setup

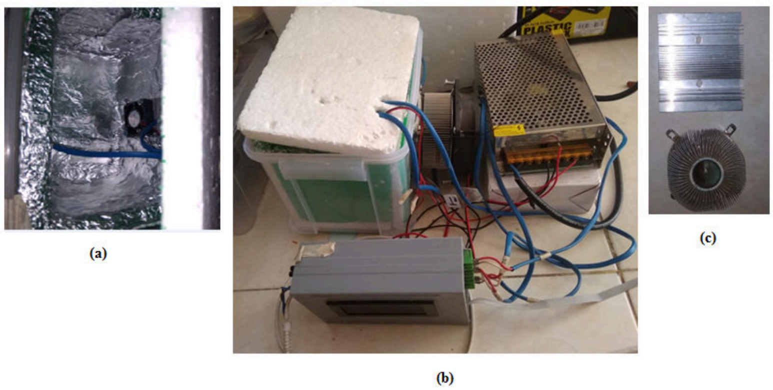

Figure 2. An Experimental Apparatus. (a) Cooling Box; (b) Electrical Equipment; (c) Heat sink.

3. RESULT AND DISCUSSION

Experimentally, research was conducted on thermoelectric cooler boxes with different heat sinks and the results described in the tables and graphs below.

Table 1. Calculation Data

Time [s]	q_c (W)	q_a (W)	q_w (W)	q_h (W)	P (W)	COP_C	COP
Heatsink 1							
1800	17.500	0.018	17.482	37.057	19.557	8.481	0.895

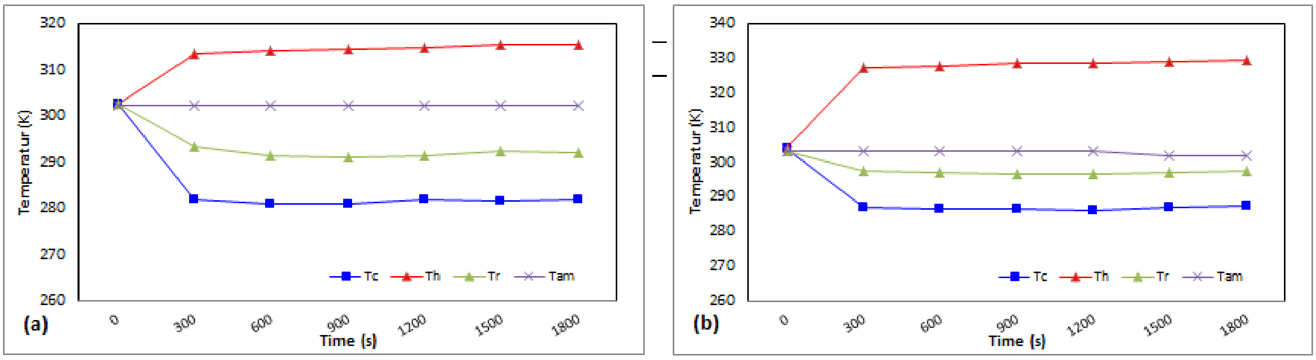

Figure 3. Graph of Temperature - Time (a)Heat sink 1, (b)Heat sink 2

In Figure 3, it can be seen the graph of the relationship between cold side temperature (T_c), hot side temperature (T_h), cooling room temperature (T_r), and ambient temperature (T_{am}) against time for 1800 seconds. Tam showed stable conditions around 300 K until the end of the test. Incorporating a straight profile heat sink, Tc decreases up to 280 K, and Th increases to 315 K. On the use of a circular profile heat sink, T_c decreases up to 287 K and Th increases to 329 K. The effects of decreasing T_c and increasing Th for 1800 seconds can be seen. At a decrease in the cooling room temperature of up to 292 K using a straight profile heat sink and a decrease in the cold room temperature of up to 297 K with the use of a circular profile heat sink. It shows that the use of a straight profile heat sink on the cooler can achieve a lower temperature.

Figure 4a shows that the heat value is absorbed by the cold side of the thermoelectric (q_c) by using a straight and circular profile heat sink. The qc value of 17.5 W is indicated by using a straight profile heat sink on the cooler. This value indicates a higher heat absorption than q_c when using a circular heat sink of 14.4 W. Following the thermoelectric working principle based on the Peltier effect, heat is absorbed from the cold side by qc, and heat is released into the environment at qh. The difference between the two heats is the amount of electric power needed [10], [11]. As shown in equation (4), the energy balance equation can be seen as the value of qh, which is determined from the value of q_c and electric power (P).

Graph 4b shows the calorific value released by using a straight profile heat sink. The graph shows that the ql value is higher at 37 W compared to the use of a circular profile heat sink, namely 34 W. This value also shows that the use of a straight profile heat sink can increase heat absorption and release to reduce the cooling room temperature.

The heating value absorbed from the air in the cooling room can be determined using equation (2) and is shown in Figure 4c. In the use of a straight profile heat sink, it is shown that the heat value absorbed from the cooling room air after 1800 seconds is 0.018 W. The heat value is higher than the heat absorbed from the cooling room air using a circular profile, namely 0.01 W. Likewise, the heat absorbed from the room wall the coolant can be determined from equation (5). In Figure 4d, it is shown that the heating value absorbed from the cooling room wall (q_w) with the use of a straight profile heat sink has a higher value, namely 17.4 W when compared to the heating value with the use of a circular profile heat sink, which is 14.4 W.

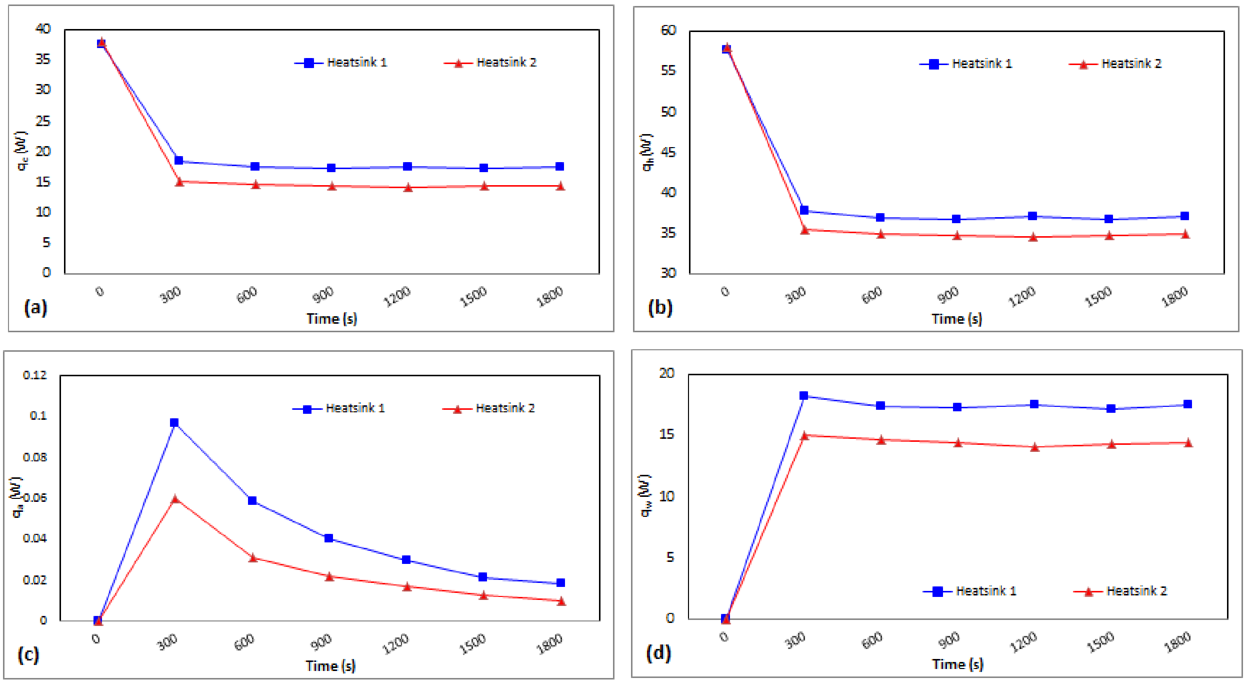

Figure 4. Heat Flow Rate (a) q_c, (b) q_h, (c) q_a, (d) q_w

In this study, a thermoelectric coupled with a heat sink and fan was used to achieve the cooling room's temperature stability by taking into account the heat load of the air and the walls of the cooler. As quoted in Afdhal's research, the greater the cooling load given to the cooler, the longer the temperature stability of the box can be achieved because more energy is needed to lower the cooler's temperature [12].

The latest parameter that shows the cooler's performance is the COP, which can be determined using equation (6) for the COP Carnot and equation (7) for the experimental COP and shown in Figure 5. In a cooler with a straight profile, it produces a COPC of 8.4. This value indicates a higher performance value than a circular profile heat sink, which shows a COPC of 6.8, as shown in Figure 5a. Furthermore, for the experimental COP shown in Figure 5b, the cooler's performance with a straight profile heat sink shows the COP_{exp} value, which is 0.8 higher than COP_{eksp}, which is using a protective profile that is 0.7. It indicates that the use of a straight profile heat sink in the cooler results in better performance.

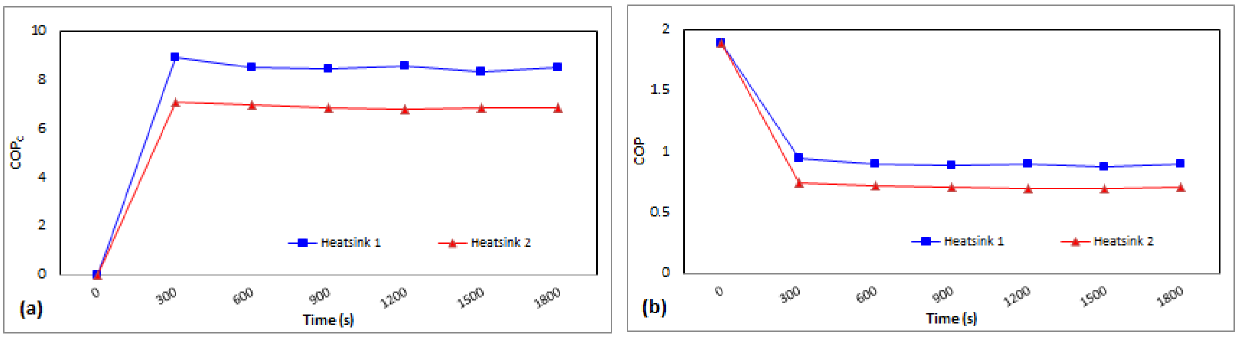

Figure 5. (a). COP Carnot; (b). COP Experimental.

4. CONCLUSION

In this study, experimental testing of thermoelectric performance on a cooler measuring 150 mm x 150 mm x 210 mm, the thermoelectric used is TEC-12706 and a heat sink with a straight and circular profile. The results of testing and analysis concluded that the best performance in the thermoelectric cooler is the use of a heat sink with a straight profile measuring 200mm x 120 mm x 35mm. The use of electric power for the thermoelectric 19.5 W, the heat absorbed on the cold side (q_c) 17.5 W, heat which is released on the hot side (q_h) 37 W, heat absorbed from the cooling room air (q_a) 0.018 W, heat absorbed from the cold room wall (q_w) 17.4 W, COPC of 8.4 and COP_{eksp}. equal to 0.8.

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6. ACKNOWLEDGMENT

Thanks to the P3M Ujung Pandang State Polytechnic, Beginner Lecturer Research can be carried out in 2020, funded by the Ujung Pandang State Polytechnic DIPA the Assignment Research Implementation Agreement Letter Number: B / 40 / PL10.13 / PT.01.05 / 2020, April 13, 2020. Thanks to the entire SNP2M 2020 State Polytechnic Ujung Pandang committee so that this research can be published.