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Preliminary investigation of performance and temperature distribution of thermoelectric cooler box with and without internal fan Abstract. An experimental performance analysis of thermoelectric refrigerator using fin and without fin in this study is presented. The results show that the inner temperature of water-cooled thmelecic rrerrot 2o 08/m fw rate whs abu. °C fr. L/min flow rate at the end of 2-h experiment.

COP value of thermoelectric refrigerator is 0.23 in the flow rate 1.5 L/min while COP is 0.19 in the flow rate 0.8 L/min at the end of 25 min cooling times. When it comes to 8 V system voltages, COP of the thermoelectric refrigerator is about 0.41 at the end of 25 min operating period for the flow rate 1.5 L/min. This study concludes that the performance of heat sink used in this study has as good as other liquid water-cooled systems used to absorb heat from thermoelectric modules hot side. Keywords: cooler box, thermoelectric refrigeration, fan heat sink, heat sink, temperature distribution, COP 1.

Introduction Refrigeration machine is one of the important needs of modern society. It is kind of process of moving heat from bounded system with lower temperature compare with outside environment. To keep food, stay fresher for some period is one of the familiar applications for this process.

Several cooling systems have been designed by researchers since 1834 [1] to facilitate food storages. Vapor compression refrigeration is the most widely used method. Although vapor-compression refrigeration has gained the dominance HVAC market, but the refrigerants used in these systems have destructive effects on the earth environment [2].

According to the newest global agreement about climate change which attended by over 1000 delegates in Kigali, Rwanda, 197 countries agreed to reduce using hydrofluorocarbons (HFCs) by 2019 [3]. The summit objective was to alleviate greenhouse gasses effect which resulted in climate change and therefore the HFC refrigerants should be phase out as soon as possible. Thus, efforts to develop other alternative refrigeration systems which eco-friendlier are still considered important for the next future.

Thermoelectric cooler is one type of refrigeration system that is environmentally friendly because it does not use refrigerants which have potential damaging the ozone layer. Their working principle based on two effects simultaneously Seebeck effect and Peltier effect [4]. A thermoelectric cooler module (TEM) or peltier module is a device which transfer thermal energy from lower to higher temperature by the input of dc power.

It is consists of a group of thermoelectric couples wired electrically in series. The device commonly used as a refrigerator or heat pump. This solid-state refrigeration was invented almost two-century ago but becomes popular application recently. Low coefficient of performance (COP) is the main shortcomings of thermoelectric cooling module, especially in large applications.

Therefore, the thermoelectric application has restricted for cases which energy is not the main issues. Increasing the performance (COP) of the thermoelectric is difficult to achieve due to low ZT value (figure of merit) of peltier module [5]. During recent years, quite a lot of study about thermoelectric refrigeration have been performed on evaluated its performances.

Min and Row [6] performed a study about the performance of TE domestic refrigerator, which particularly considered COP and cooling rate. The thermoelectric COP around 0.3-0.5 was found by them at operating temperature 5°C and ambient temperature 25°C. Dai et al. [7] also showed the nearly same COP about 0.3 for thermoelectric refrigerator, however the system was driven by photovoltaic module with battery as power storage.

Solar thermoelectric refrigerator was also studied by Abdul Wahab et al. [8]. They designed it for rural areas so it must be a portable equipment. They tested and showed that the cabin temperature was decreased until 5°C from 27°C in about 44 minutes. The calculated COP they found was about 0.16. Vián and Astrain [9] designed thermoelectric refrigerator with two different heat exchanger for the hot and cold side of thermoelectric module.

Both based on the two-phase thermosyphon, one with capillary lift technology (TMP) and the other without moving part (TSV). They claimed using those two heat exchanger increased the COP system by 66% compare with similar prototype with conventional finned heat sink. Jugsujinda et al. [10] conducted an experimental test for thermoelectric refrigerator box with the cabin volume of 0.022m3.

They showed the cabin temperature decreased from 30°C to-4,2 °C in 60 minutes when using the electric current of 3.5 ampere. The COP of thermoelectric was calculated about 0.22 for the highest supply power (40,46 Watt). The COP and electric power consumption of thermoelectric refrigerator with different control temperature was experimentally studied by Martinez [11].

It was found the COP increase 64% and power consumption decrease 32% using this control system compare with conventional on/off system. Ohara et al. [12] performed a numerically study for optimum current and geometry for small thermoelectric vaccine box for inaccessible and developing communities. Using three energy conservation equations, a model of temperature hot and cold side of thermoelectric was derived, included the refrigeration cabin temperature.

They also built and tested the prototype and attained minimum temperature of 3.4°C. Mirmanto et al. [13] investigated the performance of thermoelectric refrigeration using two type of heat sink units at the hot side of peltier module. The first one was a heat sink fan (HSF) and the second was double fan heat pipe (DFHP).

They showed that DFHP has higher COP compared than HSPF, however it consumes more power than HSF. Finally, they concluded that energy consumes for HSF was more reliable of all. Mirmanto et al. [14] also investigated the performance of thermoelectric cooler box with several positions of peltier module. The box volume was 4.891 litre, and the thickness wall was 5 cm. A bottle of water with 360 ml of volume was put inside the box as part of cooling loads.

They conclude that COP decreased with time and best positioned of peltier module was on the side wall of cooler box. Previous research confirmed that thermoelectric performance is very low compared to other cooling systems, especially vapour compression system [5, 14, 15]. However, at some specific applications such as aviation, aerospace and medical, thermoelectric has higher potential utilization and irreplaceable for some particularly conditions. Therefore, thermoelectric cooling systems are still becoming one of the promising fields of refrigeration research in the next future.

The used of an internal fan for the cold sink may affect the performance of thermoelectric cooler box due to the extra energy consumption for the device. However, the effect of the fan might also increase the heat transfer coefficient of the cold sink, which might be increase the cooling rate of thermoelectric refrigeration. In this study, the effect of using internal fan was experimentally tested to ensure its effect the performance of thermoelectric.

Additionally, the temperature distribution inside the cooler box was also observed in this work. 2. Experimental setup description Fig. 1 shows the schematic experimental rig of the present study. The main components are consisting of cooler box with thermoelectric module unit, temperature data acquisition unit, power supply units for thermoelectric module, heat sink fans and cold sink, multitester units for electricity power measurement. Cooler box material was made from polyurethane board with a thickness of 40 mm.

The inner dimension for the cooler box was 240 mm x 180 mm x 130 mm. Cooler box was hermetically encapsulated well with silicone glue to minimize infiltration heat losses. TEC2-25408 double deck cooler was used as thermoelectric module for present study. It has dimension about 40 mm x 40 mm x 6 mm dimension.

Module rated of voltage and ampere was around 12-15.4 Volt and 8 amperes. Heat sink heat pipe was used as heat removal at the hot side of thermoelectric module with water as the working fluid of heat pipe. The heat sink material was aluminium and cooper. Fan dimension for heat pipe heat sink was 92 mm x 92 mm x 25 mm.

Copper block was used as the extender between the hot side of thermoelectric module and the evaporator pad of heat sink heat pipe. Meanwhile, the cold side was attached firmly with cold sink with dimension of 80 mm x 80 mm. A small fan is attached to the bottom side of cold sink and is has dimension of 40 mm x 40 mm x 15 mm.

The supplies power for the thermoelectric module was conducted using fluke digital multitester with 0.05% accuracy. Digital multitester also measured the cold sink and heat sink power consumes. All the power consumes by the device are important parameter for calculating the performance level.

All the contact resistance between heat sink, thermoelectric module, cold sink and block copper was minimize with high thermal conductivity of thermal grease. The temperatures data was measured by type-K thermocouples which was calibrated previously (uncertainty around ± 0.5°C). The thermocouples were connected to National Instrument data acquisition (NI 9213 and NI 9274).

Six thermocouples are used specifically only to measure the temperature distribution in the cooler box (C1, C2, C3, C4, C5 and C6 at Fig.1). The others are placed on the both sides (cold and hot) of the thermoelectric module, the inner and outer walls of the cooler box and the environment. 3. Experimental Analysis The main goal of this present study was to investigate the cooling performance of thermoelectric with and without the internal fan of cold sink.

The COP of thermoelectric refrigerator is calculated from cooling capacity of the thermoelectric module divided by all electrical power consumption to the cooler, which is defined on the following equations: ?????? = ?? ? ?? ?? ?????? (1) ?? ? ?? = ?? ? ?? + ?? ? ?? + ?? ? ???????? ?????? (2) ?? ?????? = ?? ?????? ?????? ?????? + ?? h ?????? ?????? ?????? + ?? ?????? (3) where ?? ? ?? (watt) is total rate of refrigeration load of thermoelectric cooler box and it was calculated from expression (2). ?? ? ?? is consist of the heat transfer of air inside the cabin box ?? ? ?? and heat transfer loss through the walls of box ?? ? ?? to the environment.

It is also defined as active heat load as stated by several literature [9, 10, 13, 14]. Heat generation by internal fan was pointed by notation ?? ? ???????? ?? which also calculated as part of refrigeration load. The power consumes of cooler box indicated by ?? ?????????? (watt), which is express in equation (3).

At this present study, air is the product load and therefore the cooling capacity was calculated based on the air property, which is easily found at many literature [16, 17] using the equations (4) below. ?? ? ?? = (4) E is the energy (J), is the air heat transfer rate (watt), is the mass of air (kg), is the specific heat of air (J/kg K), is the temperature gradient per unit time.

Heat transfer loss through the walls of box calculated using the equation (5) below; (5) where A is the total heat transfer surface of cooler box, U is the overall heat transfer coefficient, is the average temperature of refrigerated space (C1 until C6) and is the ambient temperature. The overall heat transfer coefficient is calculated using equation (6) below.

?? = 1 1 h ?????? + ?? ?? ?????? + 1 h ?????? (6) When using internal fan, the heat transfer coefficient at cold sink is calculated using correlation given by Parmelee and Huebscher [9]. It is given below as equation (7) and (8). ???? = 0 , ???? 1 / 3 · (7) ???? = (8) Fig 1. Schematic of experimental setup. 4. Results and Discussion 4.1. Temperatures trend of thermoelectric cooler Fig. 2 illustrates the temperature variations of refrigerator for 1.5

L/min flow rate of water cooled the thermoelectric module hot side. We can see that the cold side temperature of the thermoelectric cooling unit decreases to 5 °C in the 10 min then drops subzero temperatures after 25 min. In the end of 120 min, the inner temperature of refrigerator reaches about 0.04 °C. The inner temperature of refrigerator was decreased rate of 0.6

°C/min in the time interval 0 25 min. As the flow rate of water that cools the hot side of thermoelectric module increases the inner temperature values of refrigerator decreases. Specifically the temperature drop increase up to 59% when the flow rate of water that cooled the thermoelectric module hotside is 1.5 L/min instead of 0.8 1 L/min.

CDP of the refrigerator for the flow rate 1.5 L/min is shorter than other flow rates. When compared to Figs. 3 5, it can be seen that shortest time to reach 5 °C is for the flow rate 1.5 L/min. The elapsed time in this condition is 40 min. Variation of COP with time for different flow rates of water that cools the hot side of thermoelectric module is presented in Fig. 3.

As shown in this figure, when the flow rate of cooling water is 1.5 L/min, COP value of thermoelectric refrigerator is 0.23 while the flow rate of cooling water is 0.8 L/min COP value of thermoelectric refrigerator is 0.19 in the end of 25 min operating period. COP of the thermoelectric refrigerator decrease with time and inner temperature. For the 1.5 L/min flow rate, COP value decrease from 0.4 to 0.09.

As the amount of heat that received form the thermoelectric module hot side increase COP value of thermoelectric refrigerator increases. As the water flow rate increases, the efficiency of thermoelectric module increases. Therefore, power consumption of the thermoelectric modules decreases. But, due to increased power consumption of the pumps, total COP of the refrigerator can be decrease.

The present study makes it clear that the heat receiving from thermoelectric module hot side is very important for the performance of thermoelectric refrigerator.The use of sections to divide the text of the paper is optional and left as a decision for the author. Where the author wishes to divide the paper into sections the formatting shown in table 2 should be used. Fig.

2 Temperature trends of the experimental data for TEC 10 Volt with and without internal fan. Fig. 3 Temperature trends of the experimental data for TEC 12 Volt with and without inside fan. 4.2.Temperature distribution inside the cooler box Fig. 4 Temperature distribution inside cabin of the cooler box, a) with fan (F) b) without fan (w/F). 4.3.Heat transfer and performance analysis Numbering Fig.

5 a) Comparison of heat transmitted from air (Qa) and heat flow enter the cabin of cooler box from environment (Qw) for fan and without fan, b) Comparison of QT for fan and without fan. Fig. 6 COP with and without fan for each power consumes, a) transient COP, b) average COP Fig. 5 depicts COP values of thermoelectric refrigerator for different systems voltages. The maximal COP is about 0.41 for 8 V in the end of 25 min operating period.

When the voltage of system is set 12 V, COP is about 0.23 in the end of 25 min operating period. The cooling performance of the thermoelectric refrigerator investigated in this study is listed in Table 5. It can be seen in this table that the performance of minichannel heat sink used in the study has good as other system systems used to absorb heat from hot side of thermoelectric modules compared to data presented in Table 1.

Table 6 listed the calculated values of the tests for the water-cooled thermoelectric refrigerator at steady state when the flow rate of cooling water is 1.5 L/min. As can be read form this table, the higher difference between ambient and inner temperature the more. 5. Conclusion The electrical energy consumption of thermoelectric refrigerator investigated in this study is much greater than the conventional cooling systems.

However, due to the advantages in its accurate temperature control and compact. structure, the thermoelectric refrigerators can be preferred in specific applications. On the other hand, the thermoelectric refrigerators can be powered by direct current (DC) electric sources as photovoltaic cells. Thus, especially for portable applications, these systems are promising as non-refrigerant systems. 6.

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